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INTERNATIONAL NICKEL

Press Reference Book 1970

The purpose of this book is to present concise, up-to-date information about the activities and operations of The International Nickel Company of Canada, Limited, and its two principal subsidiaries, The International Nickel Company, Inc. in the United States and International Nickel Limited in the United Kingdom.

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We hope you will find this manual a helpful source of information about International Nickel, the world's leading nickel mining and marketing organization.

In these pages, you will find information about International Nickel's mines, plants, exploration, research and development efforts, as well as its marketing activities.

Also included are a ten-year review of financial facts, a brief history of the organization, and biographies of the company's senior officers.

SCOPE OF OPERATIONS

The International Nickel Company of Canada, Limited is the world's leading producer of nickel, which it markets throughout the free world. The company is also an important producer of copper and the platinum-group metals. Other by-products recovered in its nickel operations include iron, cobalt, gold, silver, selenium, tellurium and sulphur.

Personnel: At the end of 1969, the company and its subsidiaries had 34,321 employees in 18 countries, including 25,434 in Canada, 4,591 in the United Kingdom, 3,893 in the United States and 403 in other countries.

Nickel Deliveries: In 1969, these totaled 382,170,000 pounds of nickel in all forms, compared with 480,840,000 pounds in 1968. A 128-day strike at the Ontario operations accounted for the reduction in deliveries in 1969.

Deliveries of Other Metals: The company delivered 208,220,000 pounds of copper in 1969, compared with 314,160,000 pounds the previous year. Deliveries of the platinum-group metals (platinum, palladium, rhodium, ruthenium, iridium and osmium) and gold were 421,500 troy ounces last year, compared with 440,900 ounces in 1968. Deliveries were affected by the 128-day strike at the Ontario operations. Iron ore deliveries amounted to 758,000 long tons, compared with 654,000 long tons in 1968.

Shareholders: The number of shareholders of record at December 31, 1969 was 84,219. The company's shares are listed on the Toronto, Montreal, New York, London and Scottish stock exchanges, and are also traded on other principal stock exchanges throughout the world.

Subsidiaries: The company has two major subsidiaries engaged in marketing and research activities -- The International Nickel Company, Inc. based in the United States and International Nickel Limited in the United Kingdom. International Nickel's worldwide family of affiliates includes a number that are marketing-oriented; others specialize in exploration and development and still others produce nickel and nickel-alloy rolling-mill products.

Mines: The company's 11 producing mines are located in the Sudbury District of Ontario -- the free world's principal source of nickel--and in the Thompson area of northern Manitoba. Eight new mines are under development in Canada, and potential ones are being explored for or developed in several other countries.

PRINCIPAL PROPERTIES, PLANTS AND LABORATORIES

Producing Mines

SUDBURY DISTRICT, ONTARIO - Creighton, Frood-Stobie, Garson, Levack, Murray, Crean Hill, Clarabelle, Maclennan and Totten
THOMPSON DISTRICT, MANITOBA - Thompson and Birchtree

Concentrators

SUDBURY DISTRICT, ONTARIO - Copper Cliff, Creighton, Levack and Frood-Stobie
THOMPSON DISTRICT, MANITOBA - Thompson

Smelters

COPPER CLIFF, ONTARIO - Nickel oxide sinters
CONISTON, ONTARIO
THOMPSON, MANITOBA

Iron Ore Recovery Plant

COPPER CLIFF, ONTARIO - Iron ore; soluble nickel oxide

Refineries

PORT COLBORNE, ONTARIO - Nickel metal, osmium
THOMPSON, MANITOBA - Nickel metal; elemental sulphur
COPPER CLIFF, ONTARIO - Copper; gold, silver, selenium, tellurium; semi-refined platinum-group metals; nickel sulphate
CLYDACH, WALES - Nickel metal (pellet and powder); nickel and cobalt salts and oxides
ACTON (LONDON), ENGLAND - Platinum, palladium, rhodium, ruthenium and iridium

Research Laboratories and Pilot Plants

SHERIDAN PARK AND PORT COLBORNE, ONTARIO
STERLING FOREST, NEW YORK, AND HARBOR ISLAND, NORTH CAROLINA, U.S.A.
BIRMINGHAM, ENGLAND, AND CLYDACH, WALES

Rolling Mills

Plants - HUNTINGTON, WEST VIRGINIA, AND BURNAUGH, KENTUCKY, U.S.A.;
HEREFORD, ENGLAND - Wrought nickel and high-nickel alloys

Research Laboratories - HUNTINGTON, WEST VIRGINIA, U.S.A.;
HEREFORD, ENGLAND

CANADIAN FACILITIES

Ontario Division

This division encompasses the free world's largest nickel mining and refining complex -- a railway- and pipeline-linked network of mines, mills, smelters and other facilities located for the most part within a 30-mile radius of Copper Cliff in the mineral-rich Sudbury District. It also includes an electrolytic nickel refinery and process research stations some 300 miles to the south at Port Colborne.

The division had some 21,700 employees, as of spring 1970, and engaged in the production, processing and treatment of nickel.

In the Sudbury District of Ontario, the company currently operates eight underground mines and one open-pit mine. Expansion projects are under way at these producing mines and at associated processing facilities. Additionally, six new mines are under development in Ontario, five in the Sudbury area and the other some 450 air miles to the northwest near Thunder Bay. (See "Exploration and Development.")

Ores from the Sudbury District contain nickel, copper and iron in sulphide form, and other elements. The company's principal reduction operation is at Copper Cliff, adjacent to the city of Sudbury. Its facilities include: a 26,000-ton-per-day concentrator; roasting, reverberatory, oxygen-flash smelting and blast furnaces; converters; a copper-nickel separation plant and a fluid-bed roaster plant for the production of nickel oxide sinters. Other concentrators are located near the Frood-Stobie, Creighton and Levack mines; they have daily capacities of 26,000, 12,000 and 6,000 tons of ore, respectively. There is also a smelter at Coniston.

Two oxygen plants with a combined capacity of more than 1,100 tons per day supply the oxygen requirements for the smelting operations.

Nickel intermediates from the Sudbury District are refined at Port Colborne, where pure nickel is produced in cathode form. At Copper Cliff, the company produces the following nickel products: nickel oxide sinters, soluble nickel oxide and nickel sulphate. By-products from the nickel-processing operations include: copper, iron, ore, gold, silver, selenium, tellurium and semi-refined platinum-group metals. The latter are sent to Acton (London), England, for final processing.

A major new nickel refinery using an Inco-developed process involving the separation of nickel as nickel carbonyl under pressure (see "Research") is being built at Copper Cliff. It is scheduled for completion in late 1972, and will have an annual capacity of 100 million pounds of nickel in the form of pellets and 25 million pounds of nickel in the form of powders.

A new mill with a capacity of 35,000 tons of ore a day is under construction at Copper Cliff that will provide increased milling capacity, upgrade the metal content of the smelter feed and provide increased over-all metal recovery. It is scheduled for completion in 1971.

At the Copper Cliff iron ore recovery plant, a nickeliferous pyrrhotite is treated by an atmospheric-pressure ammonia leaching process for the recovery of nickel and the production of high-grade iron ore. This plant now has an annual capacity of 900,000 long tons of iron pellets containing 68 per cent iron. An expansion project will increase the plant's capacity by some 30 per cent upon completion in 1972.

Sulphur dioxide from the iron ore recovery plant roasters and from smelter gas is supplied to nearby plants of Canadian Industries Limited for the production of sulphuric acid and liquid sulphur dioxide. The capacity of the sulphuric acid facilities at the iron ore recovery plant is 800,000 tons per year. This sulphuric acid complex is the world's largest operating on smelter gases. A new plant with an equal capacity is being built as a result of which all the sulphur dioxide produced from the nickel refinery and iron ore recovery plant will be recovered.

Manitoba Division

Four hundred miles north of Winnipeg, International Nickel's operations at Thompson constitute the free world's first fully integrated nickel mining and refining complex. Commercial production from the Thompson mine and associated processing facilities began in 1961. The Thompson refinery employs a process for the direct electrorefining of nickel-matte anodes. Elemental sulphur, a copper precipitate and cobalt oxide are by-products of this process. Some 4,300 employees are engaged in the production, processing and treatment of nickel ore at the Thompson complex.

The Birchtree mine, a major addition to the Thompson complex, came into regular production early in 1969. Surface work as well as underground development is under way at the Soab mine in time for projected operations in 1970. At the Pipe mine, which will come into production by late 1971, dredging of overburden for open-pit mining was completed late in the summer of 1969. Shaft sinking for the underground portion of the mine has been completed. A 48-mile railroad has been completed and links the Soab and Pipe mines to the Thompson ore-processing complex. A 30-mile railroad spur links the plant area and the town of Thompson to the Canadian National Railway's Hudson Bay Line, extending from Winnipeg to Churchill.

In 1972, the company's Manitoba facilities are expected to have an annual production capability of 170,000,000 pounds of nickel.

UNITED KINGDOM REFINERIES

International Nickel's refinery at Clydach, Wales, is the largest in Western Europe. Dating from 1900, this refinery was recently modernized and now is one of the most technologically advanced nickel refineries in the world. In addition to pure nickel pellets, its products include: nickel powder, iron powder and a wide range of salts and oxides of nickel and cobalt.

At Acton, semi-refined platinum-group metals from Canada are treated to recover pure platinum, palladium, rhodium, ruthenium and iridium.

RESEARCH AND DEVELOPMENT

International Nickel maintains extensive metallurgical research facilities in Canada, the United States and the United Kingdom. Its process metallurgy activities are located at the J. Roy Gordon Research Laboratory in Sheridan Park, near Toronto; at the three pilot-plant research facilities located at Port Colborne, Ontario, and at Clydach, Wales.

The two principal product research laboratories are the Paul D. Merica Research Laboratory, Sterling Forest, New York, and the Birmingham Research Laboratory, Birmingham, England. Both specialize in research on alloys of nickel. Nickel-containing alloys and other materials are tested in natural marine environments at International Nickel's Francis L. LaQue Corrosion Laboratory, near Wilmington, North Carolina.

MARKETING

International Nickel has a worldwide marketing organization with central sales and marketing offices in Toronto, New York and London. In the United States, marketing functions are carried out on a local level by the 11 district offices of The International Nickel Company, Inc. Marketing activities are also conducted by affiliates in Australia, Belgium, France, India, Italy, South Africa, Japan, Spain, Sweden, Switzerland and West Germany.

ROLLING MILL DIVISION

Rolling mills for the production of nickel and nickel alloys are operated by the Huntington Alloy Products Division of The International Nickel Company, Inc. at Huntington, West Virginia, and Burnaugh, Kentucky, and by a wholly owned affiliate of International Nickel Limited, Henry Wiggin & Company, Limited, Hereford, England.

The $30,000,000 expansion program at the Huntington Division's Burnaugh plant is well advanced. The new vacuum induction melting facilities became operational in 1969; production of extruded products is anticipated late in 1970.

Construction of new merchant mill facilities at the Huntington plant is currently under way. First production of hot-rolled wire rod is expected during the second half of 1970.

The Huntington Division and Henry Wiggin have independent marketing and research staffs and facilities. A subsidiary company, Nickel Alloys International S.A., with headquarters in Brussels, markets Huntington and Henry Wiggin products throughout Continental Europe. Australasian Nickel Alloys, in Melbourne, a division of International Nickel Australia Limited, also markets these products.

Deliveries of alloy products by the company's rolling mill divisions in the United States and the United Kingdom totaled 109,710,000 pounds in 1969, compared with 96,790,000 pounds in the previous year.

INTERNATIONAL NICKEL AROUND THE WORLD

Parent Company:

THE INTERNATIONAL NICKEL COMPANY OF CANADA, LIMITED

In the United States:

THE INTERNATIONAL NICKEL COMPANY, INC.

In the United Kingdom:

INTERNATIONAL NICKEL LIMITED

Continental Europe:

International Nickel Benelux S.A., Brussels
International Nickel France S.A., Paris
International Nickel Oceania S.A., Paris
International Nickel Deutschland G.m.b.H., Dusseldorf
International Nickel Italia S.p.A., Milan
International Nickel Iberica Limited, Madrid
International Nickel (Nordiska) Aktiebolag, Stockholm
International Nickel A.G., Zurich

Asia:

International Nickel (India) Private Limited, Bombay
International Nickel Japan Ltd., Tokyo

Australasia:

International Nickel Australia Limited, Melbourne

South Africa:

International Nickel S.A. (Proprietary) Limited, Johannesburg

High-Nickel Alloy Production and Marketing (outside of the United States):

Henry Wiggin & Company, Limited, Hereford, England
Australasian Nickel Alloys
Division of International Nickel
Australia Limited, Melbourne
Nickel Alloys International S.A., Brussels

Exploration and Development:

Canadian Nickel Company Limited, Toronto
Exploraciones y Explotaciones Mineras Izabal, S.A.
(Exmibal), Guatemala City
International Nickel Australia Limited, Sydney
P.T. International Nickel Indonesia, Djakarta

THE INTERNATIONAL NICKEL COMPANY, INC.
New York, New York

In the United States, International Nickel provides technical and marketing services on the use of nickel and nickel-containing materials from 11 district offices:

Chicago, Illinois	Houston, Texas
Cleveland, Ohio	Los Angeles, California
Dayton, Ohio	New York, New York
Detroit, Michigan	Pittsburgh, Pennsylvania
Hartford, Connecticut	Washington, D.C.

Wilmington, Delaware

The Huntington Alloy Products Division, Huntington, West Virginia, has division sales offices in:

Atlanta, Georgia	Houston, Texas
Bloomfield, Connecticut	Huntington, West Virginia
Buffalo, New York	Natick, Massachusetts
Chicago, Illinois	Pittsburgh, Pennsylvania
Cincinnati, Ohio	San Francisco, California
Cleveland, Ohio	Seattle, Washington
Detroit, Michigan	St. Louis, Missouri
Glendale, California	Union, New Jersey

Wilmington, Delaware

NICKEL

Nickel is used mainly as an alloying element, providing engineering properties such as strength, toughness, heat and corrosion resistance to materials. It also has important applications in the unalloyed state, particularly as a plating material, and in chemical forms.

Nickel was identified and isolated as a separate element in the 18th century by the Swedish scientist Axel F. Cronstedt, also credited with having given it its name. The metal had been previously known to the miners of Saxony as "kupfernickel" (Old Nick's copper). However, implements containing nickel are known to have been used as far back as 5,000 years ago in Mesopotamia.

Since 1905, Canada has been the world's largest producer of nickel. Nickel ores are also mined in New Caledonia, the United States, Australia, Finland, South Africa, Greece, Latin America, the Soviet Union and Cuba.

It was in 1905 that the original MONEL* nickel-copper alloy (now designated MONEL alloy 400), with its excellent corrosion-resistant properties, was developed. As the first nickel-base alloy to gain widespread commercial acceptance, it did much to demonstrate the advantages of nickel in alloyed form.

Stainless steels are by far the largest alloying market for nickel. They are noted for their corrosion resistance, strength, toughness and appearance. Other major uses of nickel are in high-nickel alloys (widely used in jet engines) for high-temperature strength, and in electroplating for appearance and corrosion resistance. Nickel also adds strength and toughness to constructional steels and to iron and steel castings. Copper and brass products containing nickel are widely used in marine applications.

*International Nickel Trademark

ESTIMATED FREE WORLD NICKEL CONSUMPTION BY MAJOR FIELDS OF APPLICATION

Field	Estimated Millions of Pounds 1969		1968	
Stainless Steels	320	39%	307	37%
High-Nickel Alloys	131	16%	119	14%
Nickel Plating	115	14%	124	15%
Constructional Alloy Steels	90	11%	91	11%
Iron & Steel Castings	74	9%	81	10%
Copper & Brass Products	24	3%	27	3%
All Others	66	8%	81	10%
Free World Total	820	100%	830	100%

Free world consumption of nickel by major consuming areas, according to estimates made early in 1970, follows: The United States remains the leading nickel-consuming nation (310 million pounds in 1969). Continental Europe and the United Kingdom consumed 310 million pounds; Japan, 150 million pounds; Canada, 28 million pounds; and other free world countries, 22 million pounds.

PRIMARY NICKEL PRODUCTS

To satisfy the diverse raw material requirements of its customers, International Nickel supplies primary nickel in a variety of forms. The most widely consumed is electrolytically refined nickel produced at the organization's Canadian refineries. This is available to customers in a variety of standard sizes, accommodating all types of melting furnaces and plating baskets. A special form of electrolytic nickel with sulphur added in controlled quantities is also produced specifically for use as an anode material by the plating industry.

Another important primary nickel product, widely used throughout Europe for alloying, is the nickel pellet. At International Nickel's refinery in Clydach, Wales, nickel pellets are produced by means of the carbonyl process in which nickel is separated from impurities by being transformed to a gaseous state and then back to a solid. In Canada the new Copper Cliff refinery will have a production of 100 million pounds of pellets annually when it is completed in 1972.

Nickel oxide sinter, an economical primary nickel product, is especially useful in the manufacture of stainless steel and other nickel alloy steels. This dense, granular product is available in two forms, containing either 75 or 90 per cent nickel. It is packaged in steel drums designed for direct charging into open hearth, basic oxygen, electric arc and induction furnaces.

Nickel powders for powder metallurgy and other uses are also produced by International Nickel, as are oxides and salts of nickel for various applications in the chemical process industries.

COPPER

International Nickel ranks among the major free-world copper producers. This metal is found in substantial quantity in many of the nickel-containing ores and the company mines.

Blister copper from the Copper Cliff smelter is refined by the copper refining division, formerly a subsidiary known as Ontario Refining Company Limited. From this name is derived the registered brand and trademark ORC, identifying the various products of the refinery, which include cathodes, wire bars, billets, cakes and other shapes convenient for copper and copper alloy fabrication. ORC brand copper is marketed chiefly in Canada and Europe.

PLATINUM-GROUP METALS

International Nickel is also one of the world's leading producers of the platinum-group metals -- platinum, palladium, rhodium, ruthenium, iridium and osmium.

The principal uses of the platinum-group metals are industrial. Characteristics that make them important to industry include: resistance to oxidation and corrosion, peak catalytic activity and high melting points.

The platinum-group metals, notably platinum, palladium and rhodium, are also used in jewelry and the decorative arts.

Platinum

Most plentiful of the group. Used as catalyst in the petroleum and chemical industries. Excellent resistance to corrosion and oxidation at elevated temperatures.

Palladium

Widely used for electrical contacts. Also serves as catalyst in synthesis of organic compounds requiring hydrogenation or dehyrogenation for such products as vitamins and antibiotics. Palladium-containing brazing alloys offer exceptional combinations of properties for metal-to-metal joining at temperatures as high as 2260 F.

Rhodium, Ruthenium, Iridium, Osmium

Principally used as alloying additions to platinum or palladium, frequently as hardeners. Rhodium in the electroplated form is used in a variety of contact applications in the electrical and electronic industries. Current uses for osmium are principally in the chemical area.

INTERNATIONAL NICKEL'S DELIVERIES OF NICKEL,
COPPER AND PLANTINUM-GROUP METALS AND GOLD (1960 - 1969)

Year	Nickel* (Pounds)	Copper* (Pounds)	Platinum-Group (Troy Ounces)
1969**	382,200,000	208,200,000	421,500
1968	480,800,000	314,200,000	440,900
1967	463,500,000	310,900,000	475,600
1966	500,200,000	293,000,000	500,900
1965	493,000,000	275,900,000	510,800
1964	444,200,000	286,500,000	544,800
1963	350,700,000	253,600,000	439,400
1962	318,200,000	267,300,000	410,800
1961	372,500,000	268,700,000	443,000
1960	351,900,000	292,500,000	409,400

*Nickel and copper figures are rounded to nearest hundred thousand pounds.

**1969 deliveries were affected by a 128-day strike at the company's Ontario Division.

Ten-Year Review of Financial and Operating Results

Expressed in thousands except where noted
(All figures expressed in U.S. currency)

	1969	1968	1967	1966	1965	1964	1963	1962	1961	1960
Net sales and other income	$ 705,300	781,300	721,300	703,300	643,000	576,300	468,700	452,400	519,300	508,100
Costs, expenses and income taxes	$ 588,800	637,600	579,500	585,100	499,200	440,500	362,400	358,200	430,500	427,400
Net earnings	$ 116,500	143,700	141,800	118,200	143,800	135,800	106,300	94,200	88,800	80,700
Per common share*†	$ 1.56	1.93	1.90	1.59	1.94	1.84	1.44	1.28	1.21	1.10
Common dividends	$ 89,300	91,500	89,100	83,100	90,300	81,300	66,300	55,900	46,900	44,500
Per common share*†	$ 1.20	1.23	1.20	1.12	1.22	1.10	0.90	0.76	0.64	0.61
Income taxes	$ 57,700	86,800	78,300	69,000	93,500	66,700	43,600	37,400	60,900	60,200
Depreciation and depletion	$ 33,500	29,300	26,100	26,200	26,500	27,500	26,200	24,300	19,900	15,500
Capital expenditures**	$ 175,200	175,400	145,700	73,000	62,700	44,400	36,000	61,000	46,000	76,000
Exploration expenditures**	$ 19,900	17,000	13,300	11,700	12,300	7,600	6,400	5,900	7,400	8,900
Total assets‡	$1,477,000	1,396,200	1,120,300	1,022,800	986,800	898,500	809,600	759,700	744,900	678,700
Ore mined—wet short tons	18,800	24,900	20,400	17,600	19,800	16,400	13,600	13,800	17,500	16,800
Nickel deliveries—pounds	382,200	480,800	463,500	500,200	493,000	444,200	350,700	318,200	372,500	351,900
Copper deliveries—pounds	208,200	314,200	310,900	293,000	275,900	286,500	253,600	267,300	268,700	292,500
Platinum-group metals and gold deliveries—troy ounces	422	441	476	501	511	545	439	411	443	409
Employees*	34,321	33,314	32,552	31,837	32,512	30,501	26,907	27,606	32,052	30,447
Shareholders*	84,219	75,587	64,207	67,120	65,965	63,993	64,178	63,425	63,412	64,942

*Units.
**Includes capitalized exploration expenditures.
†As adjusted to reflect the split of shares on a 2-for-1 basis in 1960, and a 2½-for-1 basis in 1968.
‡Does not include any value for the minerals in the major portion of the Company's ore reserves.

SHARES AND SHAREHOLDERS

As of December 31, 1969, there were 74,415,688 shares outstanding held by 84,219 shareholders of record. Records of shareholder addresses showed 58 per cent of the shareholders to be in Canada, 39 per cent in the United States and 3 per cent elsewhere. Canadian residents held 31 per cent of the number of shares outstanding, United States residents 55 per cent, and residents of other countries 14 per cent.

INCO'S CONTRIBUTION TO THE CANADIAN ECONOMY IN 1969

As the world's largest producer of nickel, International Nickel has developed markets in many countries. Through exports and purchases of supplies and services, International Nickel makes a significant contribution to Canada's economy. Details of some of these for 1969 follow:

Employees: The company employs some 25,400 people in Canada. Over 80,000 Canadians derive their livelihood, directly or indirectly, from International Nickel's operations.

Wages and Salaries: The company paid over $160,000,000 to employees in Canada.

Capital Outlay: The company spent over $150,000,000 for capital projects in Canada.

Exploration: Some $15,000,000 was expended in the search for new mineral deposits in Canada.

Purchases: In addition to capital outlays about $150,000,000 was spent in Canada for goods and services relating to metal production.

Foreign Exchange: International Nickel's activities contributed some $330,000,000 to Canada's balance of international payments.

Dividends: Canadian shareholders received over $29,000,000 in dividends in 1969. The market value of the company's shares held by Canadians, as of May 21, 1970, totaled over $800,000,000.

* All figures in Canadian funds

EXPLORATION

International Nickel conducts mineral exploration throughout Canada and various parts of the world. In recent years, as the organization's search for nickel has intensified, its prospecting teams have been flying almost a million miles annually. Their techniques include aerial geophysics and photography; ground geology, geophysics and geochemistry; and soil and rock sampling using a wide variety of equipment.

In the last 10 years, the company has spent over $110,000,000 in its search for new nickel sources, including a record $19,900,000 in 1969. More than 70 per cent of the exploration expenditures last year was made in Canada.

In addition to the company's continuing underground exploration projects in the Sudbury District of Ontario and the Thompson area of Manitoba, both at producing mines and those under development, extensive surface exploration programs are conducted in other parts of Canada by a wholly owned subsidiary, Canadian Nickel Company Limited. Last year, exploration was maintained at a high rate in Ontario, Manitoba, Quebec and Saskatchewan. At Shebandowan, underground exploration continued, while in the Sudbury District investigation of low-grade nickel mineralization at the North Range location progressed.

Canadian sulphide ores will be the mainstay of free world nickel production for the foreseeable future, and production of nickel in Canada will continue to grow. However, a very significant proportion of the world's potential nickel reserves is contained in lateritic deposits. International Nickel is actively involved in exploring for or developing lateritic deposits in Guatemala, Indonesia, New Caledonia, Australia and the British Solomon Islands. At the same time, it is investigating or developing sulphide deposits in the United States, Australia and elsewhere, as well as Canada.

Included among its exploration and development subsidiaries outside of Canada are International Nickel Australia Limited, based in Australia; Exploraciones y Explotaciones Mineras Izabal, S.A. (Exmibal) in Guatemala; and P.T. International Nickel Indonesia. The first-mentioned has acquired exploration rights to a number of areas in Australia and is also exploring in the British Solomon Islands. Exmibal is preparing to develop lateritic nickel deposits near Lake Izabal in Guatemala, while the subsidiary in Indonesia is conducting extensive survey and exploration work on the island of Sulawesi. Inco is a partner in the French company Compagnie Française Industrielle et Minière du Pacifique (Cofimpac) looking to the development of previously untapped nickel deposits in New Caledonia.

NEW MINE DEVELOPMENT IN CANADA

A current expansion and modernization program under way at International Nickel's Canadian operations, begun in 1966 and continuing through 1972, will cost an estimated $1.1 billion. To date, more than $500 million has been spent.

In 1972, International Nickel is scheduled to have eight new mines in production in Canada. This is part of the largest expansion program in the history of the company; it also involves expansions at most of the 11 producing mines in Ontario and Manitoba, and at associated processing facilities. As a result, the company's annual Canadian nickel-production capability will progressively increase and surpass 600,000,000 pounds in 1972 -- an increase of some 150,000,000 pounds, or 30 per cent. When the program is completed, International Nickel will have 19 mines in Canada, with production rates ranging from 1,000 to more than 30,000 tons of ore per day, and will have increased its capacity from 100,000 to 150,000 tons of ore per day.

Ontario: Six of the eight new mines will be in Ontario. In the Sudbury District, Copper Cliff North* and Kirkwood mines are scheduled for production in 1970 and the other four during the period 1971-1973.

In 1970, underground work will proceed that may result in the development of a new mine at Victoria in the Sudbury District, where an old mine was last worked in 1923. To permit investigations below the old workings, an estimated 100,000,000 gallons of water have been pumped out of the former mine site. Another project is in the North Range area, also in the Sudbury District, where exploration is proceeding from a 3,175-foot exploration shaft.

At the southwest corner of Shebandowan Lake in northwestern Ontario, about 50 miles west of Thunder Bay, the sixth new Ontario mine is being developed. The Shebandowan production shaft is being sunk to a depth of 2,375 feet on the south shoreline of the lake; a concentrator will be constructed about a quarter of a mile from the mine's headframe. Production is scheduled for 1972, at approximately 3,000 tons of ore per day.

Manitoba: The Birchtree mine came into regular production early in 1969. The Soab mine is expected to come into production later this year and the Pipe mine in 1971.

*Development work was completed on Copper Cliff North at the end of May, 1970.

INTERNATIONAL NICKEL'S PRODUCING MINES
Production Rates in Wet Short Tons/Day

ONTARIO DIVISION

Frood-Stobie	30,000
Creighton	20,000
Clarabelle	11,000
Levack	8,000
Murray	7,500
Crean Hill	5,000
Garson	5,000
Maclennan	1,000
Totten	500

MANITOBA DIVISION

Thompson	8,000
Birchtree	4,000

NEW MINES UNDER DEVELOPMENT
Projected Approximate Daily Capacities in Wet Short Tons

ONTARIO DIVISION

Copper Cliff North*	8,000
Little Stobie	8,000
Copper Cliff South	6,000
Coleman	4,000
Shebandowan	3,000
Kirkwood	1,500

*development work completed at end of May, 1970

MANITOBA DIVISION

Pipe	16,000
Soab	4,000

EXPANSION PROJECTS OUTSIDE OF CANADA

During 1969, International Nickel was engaged in exploration or development in many parts of the world. The principal areas were Australia, Indonesia, New Caledonia and Guatemala.

Work also continued on properties held by the organization in Minnesota and the British Solomon Islands Protectorate. Most of the deposits are lateritic, or oxide, ores, while the company's deposits in Canada are sulphide ores.

Southwest Pacific: In Australia, International Nickel, working with The Broken Hill Proprietary Company Limited, continued its major exploration effort in the Kalgoorlie region of Western Australia where important nickel deposits have been found by others.

These efforts led to the discovery in 1969 of interesting deposits of nickel sulphide mineralization near the town of Widgiemooltha, Western Australia. Work began in April 1970 on the sinking of a 1,000-foot shaft that will permit extensive exploration at depth and the hoisting of bulk samples for metallurgical testing.

The company is collaborating with Broken Hill in work on a lateritic nickel deposit at Rockhampton, Queensland. Evaluation of this deposit continued during 1969.

At Wingelinna, Western Australia, a comprehensive study was initiated during the year to determine whether, in light of current circumstances, development of a lateritic nickel deposit discovered in the late 1950's is now economically feasible. This deposit is held by Southwestern Mining Limited, an Australian company in which International Nickel is the majority shareholder. The new study is expected to be completed by mid-1970.

Exploration is proceeding rapidly on the Indonesian island of Sulawesi, where P.T. International Nickel Indonesia, a wholly owned subsidiary, is investigating lateritic nickel deposits in a 25,000-square-mile area. Results so far have been encouraging.

Exploration and feasibility work were continued on lateritic nickel deposits in the British Solomon Islands Protectorate during 1969.

New Caledonia: On March 14, 1969, after final approval by the French Government, International Nickel entered into a definitive agreement with a consortium of public and private French interests looking to the development of previously untapped nickel deposits on the French Pacific island of New Caledonia. This agreement implements the preliminary agreement entered into in late 1967. The accord gives International Nickel a 40 per cent shareholding in Compagnie Française Industrielle et Minière du Pacifique (Cofimpac), the French company set up to develop the New Caledonian deposits.

International Nickel is charged with the technical aspects of the project and is currently completing a feasibility study that includes large-scale pilot plant testing of ore samples. This work will be completed in mid-1970 and is expected to lead to initial production in 1974.

The objective of the Cofimpac project is to add some 100,000,000 pounds of nickel a year to the world supply.

Guatemala: The Guatemalan project requires only the completion of arrangements with Guatemalan authorities before large-scale construction can begin. During 1969, work moved forward on preparation of the plant site and on preliminary mine development. Plans for the project were reviewed and modified to increase the plant capacity to 60,000,000 pounds of nickel a year and to produce in Guatemala fire-refined nickel as the end product. The Guatemalan company, Exploraciones y Explotaciones Mineras Izabal, S.A. (Exmibal), is owned 80 per cent by International Nickel and 20 per cent by The Hanna Mining Company, but provisions are being considered to allow for a participation in the project by Guatemalan and other Central American investors. Total investment in the project is currently expected to be $205,000,000.

Minnesota: Drilling continued on copper-nickel leases near Ely, Minnesota, in the United States. Evaluation of this low-grade sulphide deposit went forward.

Central America: International Nickel has been carrying out general exploration in Guatemala, Panama, Costa Rica and elsewhere.

South Africa: In 1968, the company acquired a 10 per cent interest in Impala Platinum Limited (an affiliate of the Union Corporation Limited), which is building a new platinum-group metals mining, smelting and refining establishment in South Africa. International Nickel is providing technical assistance on the platinum refining aspects of the projects. Production of platinum is scheduled to begin at an initial rate of 100,000 troy ounces per year.

International Nickel is engaged in three basic areas of research; mining research to develop improved methods of recovering nickel-containing ores; process research to seek more efficient means of recovering nickel and other elements from the ore; and product - research, which concentrates on commercial applications for nickel.

Mining Research

Mining engineers and geologists at International Nickel are continually seeking ore-recovery methods that will enable miners to work ore bodies faster, more efficiently and to greater depths.

The key to these goals is found in the development of new and improved equipment for miners to use, and innovations in bulk mining methods. International Nickel's engineers work closely with manufacturers of heavy equipment in adapting it for use in underground operations. The company's engineers are also instrumental in the design and development of new mining equipment.

With the development of diesel-powered load-haul-dumpers and other trackless mining equipment furnished with oxy-catalytic exhaust scrubbers, the company also introduced underground ramps at the No. 3 shaft of the Creighton mine in the Sudbury District. This innovation enables the company to move trackless equipment between several levels of the mine instead of restricting it to a single level, thus enabling more efficient use of the equipment. Underground ramps are being used wherever practicable in other company mines.

Process Research

The growing dependence of nickel producers on lower-grade sulphide and lateritic ores has resulted in major research efforts toward more efficient processes of extracting nickel and other metals. International Nickel's most recent innovation in the treatment of sulphide concentrates and metallurgical intermediates is the Inco pressure carbonyl process integrating pyrometallurgical, vapometallurgical and hydrometallurgical techniques. This process will be commercially implemented at the new nickel pellet and powder refinery now being constructed at Copper Cliff.

Lateritic ores to be mined at the company's proposed operations in Guatemala will be treated by a pyrometallurgical process developed by International Nickel specifically for ores of this type. Similarly, the company's joint venture with French partners in New Caledonia will rely on processes developed and/or proven out at International Nickel's laboratories and pilot plants. Special attention is also being given to the ores of Minnesota, Indonesia and Australia.

The process research work is concentrated at the J. Roy Gordon Research Laboratory in Sheridan Park, near Toronto, and at the extensive pilot plant complex at Port Colborne, Ontario. Hydrometallurgy, pyrometallurgy and vapometallurgy research and tests are carried out at these facilities on a wide variety of sulphide and lateritic ores. Some of this work is of a long-term research nature. Much of it, however, is aimed at applying as quickly as possible the company's accumulated knowledge to determine the optimum processing methods for the many different ores from deposits being explored or developed by the company.

Product Research

International Nickel's product research serves to broaden the range of commercial applications for nickel by creating marketable nickel-containing materials, by improving existing ones, by developing treatments that modify nickel alloy properties, and by demonstrating the suitability of nickel-containing materials for specific functions. Research activities are influenced by the present and anticipated needs of industry as uncovered by the company's men in the field, and by product development and application engineers.

A recent result of International Nickel's product research is a new alloying process called "mechanical alloying." The process, still in the laboratory stage, offers promise as a means of developing alloys with higher strengths at elevated temperatures for applications such as jet engine components.

International Nickel's major product research facilities are the Paul D. Merica Research Laboratory in Sterling Forest, New York and the Birmingham Research Laboratory in Birmingham, England.

Corrosion studies in these laboratories are supplemented by tests of metallic and nonmetallic materials conducted under carefully monitored and controlled conditions in both natural and modified marine environments at the Francis L. LaQue Corrosion Laboratory, located on the coast of North Carolina near Wilmington. Testing has been carried out in this location for more than three decades, and the data accumulated form a substantial part of International Nickel's file of more than 300,000 laboratory and in-service test results relating to the performance of materials in corrosive environments.

Environmental Control

International Nickel is devoting substantial effort to improving environmental conditions in areas where it operates. Attention is focused on all forms of pollution control. For the near term, the company is taking costly steps to further decrease pollutants and their adverse effects, thus bringing about a significant improvement in the environment. Beyond these steps, the longer-term answers are not simple, and many are still unknown. While there can be no spectacular overnight breakthroughs, the company is determined to make environmental protection a key objective through well-considered programs drawing upon advanced technology and involving a proper balance between meeting environmental goals and continuing the development of mineral resources.

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ALBERT P. GAGNEBIN

Senior Executive Vice President
JAMES C. PARLEE

Executive Vice President
RICHARD A. CABELL

Executive Vice President
F. FOSTER TODD

Vice President—Finance
CHARLES F. BAIRD

Secretary
WILLIAM F. KENNEDY

Comptroller
W. JOHN GOULD

Treasurer
F. M. A. NOBLET

Assistant to the Chairman
JOHN H. PAGE

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L. EDWARD GRUBB
H. FRANKLIN ZURBRIGG
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Term Expires 1970

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New York, N. Y.

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Canadian Pacific
Railway Company,
Montreal, P.Q.

PETER D. CURRY
Chairman,
The Investors Group,
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ALBERT P. GAGNEBIN*
President

JAMES H. GOSS
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A-T-O Inc.,
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ELLMORE C. PATTERSON*
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Executive Vice President,
Bethlehem Steel
Corporation,
Bethlehem, Pa.

HENRY S. WINGATE*
Chairman of the Board
and Chief Officer

*Member of Executive Committee

Term Expires 1971

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Kingston, Ont.

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VISCOUNT WEIR, C. B. E.
Chairman,
The Weir Group Limited,
Glasgow, Scotland

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R. EWART STAVERT
J. C. TRAPHAGEN
HENRY S. WINGATE

4/70

HENRY S. WINGATE

Chairman and Chief Officer
The International Nickel Company of Canada, Limited
The International Nickel Company, Inc.

Henry S. Wingate has been chairman of the board of directors and chief officer of The International Nickel Company of Canada, Limited and its United States subsidiary, The International Nickel Company, Inc., since 1960. Prior to this he had been president of both companies since 1954.

Mr. Wingate is chairman of the executive committee and a member of the advisory committee of the parent company, chairman of the executive committee of The International Nickel Company, Inc., and a director of a number of other International Nickel subsidiaries.

Mr. Wingate joined The International Nickel Company of Canada, Limited in 1935 as assistant secretary and as assistant to the president of its United States subsidiary. His association with International Nickel began in 1930 while he was on the staff of its general counsel, the firm of Sullivan & Cromwell. He was elected secretary of the parent company in 1939, a director in 1942 and vice president in 1949.

In Canada, Mr. Wingate is a director of the Bank of Montreal and of the Canadian Pacific Railway Company; and in the United States, a director of J. P. Morgan & Company, Inc., Morgan Guaranty Trust Company of New York, United States Steel Corporation, and American Standard Inc., as well as a trustee of The Seamen's Bank for Savings.

He is a member of The Canadian-American Committee of the National Planning Association, Washington, D.C., and the Private Planning Association of Canada; The Business Council, Washington, D.C.; The Canadian Institute of Mining and Metallurgy; American Institute of Mining, Metallurgical and Petroleum Engineers; Mining and Metallurgical Society of America; the executive committee of American Bureau of Metal Statistics; Council on Foreign Relations, Inc.; Association of the Bar of the City of New York; a director, vice president and member of Executive Committee of International Copper Research Association, Inc.; and a director of Societe de Chimie Industrielle, Paris. He is a trustee of the Council for Latin American and the U.S. Council of the International Chamber of Commerce. He is also a member and trustee of the United States Steel Foundation, Inc. and a member of the board of governors of Federal Hall Memorial Associates, Inc.

He is a trustee, chairman - Finance Committee, and senior board member of the National Industrial Conference Board, and a member of its Canadian Council. He is also a trustee of Carleton College, Northfield, Minnesota, and The Annuity Fund for Congregational Ministers and Retirement Fund for Lay Workers, and a member of the Congregational Board of Ministerial Relief.

Mr. Wingate is also a director of the Downtown-Lower Manhattan Association, Inc.; The People's Symphony Concerts; American Committee for the Institute for Advanced Study - Europe, Inc.; Institut des Hautes Etudes Scientifique; and a member of The Pilgrims of the United States; Canadian Society of New York; The Newcomen Society of North America; New York Genealogical & Biographical Society; Society of Genealogists (London); and New England Historic Genealogical Society. He is also lay member, Grand Central Art Galleries, Inc.

A graduate of Northfield High School, Northfield, Minnesota, Mr. Wingate attended Carleton College, receiving a Bachelor of Arts degree in 1927. He received the degree of Juris Doctor from the University of Michigan Law School in 1929. Carleton College presented him with an Alumni Achievement Award in 1956, and in 1957 he received the honorary degree of Doctor of Laws from the University of Manitoba, Winnipeg. During 1967 Mr. Wingate received the University Sesquicentennial Award from the University of Michigan, the honorary degree of Doctor of Laws from Marshall University, Huntington, West Virginia, and the honorary degree of Doctor of Laws from York University, Toronto, Ontario. In 1968 he received the honorary degree of Doctor of Laws from Laurentian University, Sudbury, Ontario.

In September 1967 Mr. Wingate received the International Palladium Medal of the American Section of the Societe de Chimie Industrielle, awarded to "an individual who has distinguished himself by an outstanding contribution to the chemical industry."

Mr. Wingate is a member of the Toronto Club, Toronto; The Mount Royal Club, Montreal; The International Club of Washington, D.C., Inc.; The Duquesne Club, Pittsburgh; Laurel Valley Gold Club, Ligonier, Pa.; The Union Club, The Pinnacle Club, Economic Club, The Recess and City Midday Club (Trustee), all of New York City; and in Long Island, the Huntington Country Club and the Cold Spring Harbor Beach Club.

Mr. Wingate is married to the former Ardis Swenson. They have two children, and reside in New York City and Lloyd Neck, New York.

ALBERT P. GAGNEBIN

President
The International Nickel Company of Canada, Limited
The International Nickel Company, Inc.

Albert P. Gagnebin has been president of The International Nickel Company of Canada, Limited and its United States subsidiary, The International Nickel Company, Inc., since January 1967. He is also a director and member of the executive committee of both companies, a member of the advisory committee of the parent company and a director of a number of International Nickel subsidiaries.

Mr. Gagnebin had been executive vice president of the parent company and its United States subsidiary since 1964. Prior to this, he was vice president of the parent company for four years. He had been elected a vice president of The International Nickel Company, Inc. in 1958.

His association with International Nickel dates from 1930, when he held a summer position at its Huntington Works in West Virginia. In 1932 he joined the staff of the research laboratory of The International Nickel Company, Inc. at Bayonne, New Jersey, engaging in ferrous metals research. A co-inventor of International Nickel's ductile iron, he transferred to the New York office in 1949 to establish a group for the commercial development of this material. In 1955 he was appointed assistant manager of the Nickel Sales Department, becoming manager in 1956.

While on the staff of the Bayonne laboratory, Mr. Gagnebin was concerned with research into factors influencing the toughness of steels at sub-zero temperatures, the effect of deoxidation treatments on the mechanical properties of cast steels, and many studies on cast irons. Over a period of years, he was associated with others in fundamental studies on the solidification characteristics of iron, which eventually led to the discovery of a process for making ductile iron.

Mr. Gagnebin is vice president and director of the Tokyo Nickel Company Limited, Tokyo, Japan; a trustee of the Atlantic Mutual Insurance Company and the Bank of New York; and a director of the Abex Corporation, The Toronto-Dominion Bank, Centennial Insurance Company, Illinois Central Industries, Sterling Forest (N.Y.) Board of Design, International Copper Research Association, Inc., The American Committee for the Institute for Advanced Study - Europe, Inc., American Society for Friendship with Switzerland and Yale Engineering Association. He is also premier vice president and a councillor of the French Chamber of Commerce in the United States, Inc., and a member of the Board of Governors of the Canadian Export Association.

Mr. Gagnebin attended Yale University, receiving a Bachelor of Science degree in mechanical engineering in 1930 and a Master of Science degree in metallurgy in 1932.

In May 1952 Mr. Gagnebin and an International Nickel associate were awarded the Peter L. Simpson Gold Medal of the American Foundrymen's Society for their "outstanding work and development in the field of spheroidal cast iron." In July 1965 he was co-recipient of the Annual Award of the Ductile Iron Society "for outstanding contribution to the ductile iron industry and its technology in the field of technical contribution and industry leadership." In October 1967 he was presented with the Grande Medaille d'Honneur of L'Association Technique de Fonderie at the 34th International Foundry Congress. The medal, established in 1932, has only been awarded eight times.

He is an honorary life member of the American Foundrymen's Society; and a member of the American Society for Metals, Mining and Metallurgical Society of America, American Institute of Mining, Metallurgical and Petroleum Engineers, and the Society of Sigma Xi, a scientific fraternity. He is also a member of the Pan American Society of the United States, Woods Hole Oceanographic Institution, The Economic Club of New York; and a resident member of The Mining Club of New York.

He is a member of the Yale Club of New York, The Down Town Association, and The City Midday Club, all of New York City; and a member of the Rumson Country Club, Rumson, New Jersey; Sea Bright Beach Club, Sea Bright, New Jersey; and the Duquesne Club of Pittsburgh.

Born in Torrington, Connecticut, Mr. Gagnebin is married to the former Genevieve Hope. They have two daughters, and reside in Fair Haven, New Jersey.

JAMES C. PARLEE

Senior Executive Vice President
The International Nickel Company of Canada, Limited
The International Nickel Company, Inc.

James C. Parlee has been senior executive vice president of The International Nickel Company of Canada, Limited since January 1967, and a director since June 1965. He has also been senior executive vice president and a director of the company's United States subsidiary, The International Nickel Company, Inc., since December 1967.

Mr. Parlee had been executive vice president of the parent company since 1964. He was appointed vice president in 1960, and had been in charge of the company's operations in Canada since 1963. Prior to his appointment as assistant vice president in 1958, he worked in various supervisory capacities in the company's Canadian divisions. He joined International Nickel in 1933.

He is chairman and director of the Canadian Nickel Company, Limited; a director of The Mining Association of Canada; and a director of The National Trust Company, Limited and The Great-West Life Assurance Company.

Mr. Parlee received a Bachelor of Science degree in mining and metallurgy from the University of Alberta, Edmonton, Alberta, in 1933.

He is a member of the Canadian Institute of Mining and Metallurgy and the American Institute of Mining, Metallurgical and Petroleum Engineers, as well as the Association of Professional Engineers in both Ontario and Manitoba.

Mr. Parlee is also a member of the St. Charles Golf and Country Club and the Manitoba Club, Winnipeg; and a member of the Toronto, Toronto Hunt and Toronto Golf Clubs, as well as the York Club, also in Toronto. He is a member of the Boisclair Fish and Game Club of Mattawa, Ontario; the Rideau Club of Ottawa; and the Idylwylde Golf and Country Club of Sudbury. He is also a member of the Siwanoy Country Club, Bronxville, New York, and the City Midday Club and India House, New York City.

Mr. Parlee is married to the former Dorothy E. Walker. They have one son and reside in Bronxville, New York.

RICHARD A. CABELL

Executive Vice President
The International Nickel Company of Canada, Limited
The International Nickel Company, Inc.

Richard A. Cabell has been executive vice president of The International Nickel Company of Canada, Limited since January 1967, and executive vice president of The International Nickel Company, Inc. since April 1964. He has also been a director and member of the executive committee of the United States subsidiary since 1964.

Prior to his present positions, Mr. Cabell had been vice president of the Canadian parent company since 1960. In 1957 he was elected an assistant vice president of The International Nickel Company of Canada, Limited, as well as vice president of The International Nickel Company, Inc. Mr. Cabèll's active association with International Nickel began in 1939 when he joined Sullivan & Cromwell, the company's general counsel. He joined The International Nickel Company, Inc. in 1944 as assistant secretary.

Mr. Cabell received a Bachelor of Arts degree from the University of Virginia in 1935. He attended the University of Virginia Graduate School from 1935 to 1936 and the University of Virginia Law School, receiving a Bachelor of Laws degree in 1939.

Mr. Cabell is a director of The Toronto-Dominion Bank Trust Company. He is also chairman of the board of the Associated Hospital Service of New York (Greater New York Blue Cross), and a member of the Council on Foreign Relations, New York.

He is a member of the Canadian Club, Broad Street Club, City Midday Club, Economic Club, Knickerbocker Club, Virginians Society and National Arts Club, all of New York; and a member of the International Club of Washington, D.C.; and the Waccabuc Country Club, Waccabuc, New York.

Mr. Cabell is married to the former Cyane B. Mason. They have four children and reside in Waccabuc, New York.

F. FOSTER TODD

Executive Vice President
The International Nickel Company of Canada, Limited

F. Foster Todd has been executive vice president of The International Nickel Company of Canada, Limited since January 1967.

Mr. Todd was assigned to International Nickel's New York office as assistant vice president in April 1965, and returned to Toronto as executive vice president in charge of Canadian operations in April 1967. Previously he had been assistant vice president of the company since 1964 and general manager of the Manitoba Division since 1962. He joined International Nickel at Copper Cliff in 1929, subsequently serving in various supervisory capacities.

He is a vice president and a director of the Canadian Nickel Company and the Pineland Timber Company, Limited and an officer and director of other International Nickel subsidiaries. Mr. Todd is also a member of the board of directors of The Bank of Nova Scotia.

He received the degrees of Bachelor of Science and Engineer of Mines in 1928 from the Michigan College of Mining and Technology, Houghton, Michigan.

Mr. Todd is a member of the Canadian Institute of Mining and Metallurgy, Mining and Metallurgical Society of America, and American Institute of Mining, Metallurgical and Petroleum Engineers. He is presently a director and vice president of the Mining Association of Canada.

Mr. Todd is also a member of the Toronto Club, the Granite Club and the Canadian Club of Toronto; the Mississaugua Golf & Country Club; the Copper Cliff Club, Copper Cliff, Ontario: the Manitoba Club, Winnipeg; and the Canadian Club and the Mining Club of New York.

Born in Crisfield, Maryland, Mr. Todd became a Canadian citizen in 1941. He is married to the former Phyllis Fields. They have one married daughter, and reside in Oakville, Ontario.

CHARLES F. BAIRD

Vice President-Finance
The International Nickel Company of Canada, Limited

and

Vice President-Finance
Director
The International Nickel Company, Inc.

Charles F. Baird joined The International Nickel Company of Canada, Limited as vice president-finance in February 1969. He is also vice president-finance and a director of the United States subsidiary, The International Nickel Company, Inc.

Mr. Baird had been Under Secretary of the Navy since August 1967. He joined the Government in November 1965 as Assistant Secretary of the Navy (Financial Management).

Prior to his Government service Mr. Baird had been an executive with Standard Oil Company (New Jersey) and its affiliated companies for seventeen years. Starting his career as a financial analyst, he served as deputy European financial representative in London, financial director of Esso France in Paris and as assistant treasurer of the parent company.

Mr. Baird served as an officer in the Marine Corps in World War II and during the Korean war.

He graduated from Middlebury College, where he majored in economics. He studied at New York University Graduate School of Business Administration and in 1960 completed the Advanced Management Program of the Harvard University Graduate School of Business Administration.

A trustee of Bucknell University, Mr. Baird is a member of The Council on Foreign Relations, The Atlantic Council of the United States, The American Academy of Political and Social Science and the Council of Financial Executives of The National Industrial Conference Board. He is also a member of the Chevy Chase Club, Washington, D.C., The International Club, Washington, D.C. and India House, New York City.

Born in Southampton, New York, Mr. Baird is married to the former Norma White. They have four children and reside in Short Hills, New Jersey.

STEPHEN F. BYRD

Vice President-Industrial Relations and Personnel
The International Nickel Company of Canada, Limited

and

Vice President
The International Nickel Company, Inc.

Stephen F. Byrd has been vice president of industrial relations and personnel of The International Nickel Company of Canada, Limited since February 1970 and vice president of The International Nickel Company, Inc. since he joined the company in September 1968. Prior to his present position in the parent company, Mr. Byrd had been assistant vice president since 1968.

Prior to joining International Nickel, Mr. Byrd had been vice president - employee relations, Industrial Chemicals Division of Allied Chemical Corporation. Previously he had served in an executive capacity with Pan American Airways and Sinclair Oil Corporation.

Mr. Byrd is a graduate of City College of New York, where he majored in economics. He also received a Bachelor of Laws degree from New York Law School, and is a member of the New York State Bar. He has authored or edited several books in the employee relations field, including Management Strategy in Collective Bargaining and Front Line Supervisor's Labor Relations Handbook. He is a member of the Industrial Relations Research Association, Madison, Wisconsin.

During the Korean War, Mr. Byrd served with the U.S. Army as a member of the Judge Advocate General's Corps. While on duty in Europe, he was concerned with negotiating disputes between the U.S. government and various European nations.

Mr. Byrd is a member of the Broad Street Club, New York City. He and his wife reside in Toronto, Ontario. They have two children.

W. JOHN GOULD

Comptroller
The International Nickel Company of Canada, Limited
and
The International Nickel Company, Inc.

W. John Gould has been comptroller of The International Nickel Company of Canada, Limited and The International Nickel Company, Inc. since 1970.

Mr. Gould joined the Accounting Department of The International Nickel Company, Inc. in 1937. He was appointed chief tax accountant in 1949, and assistant comptroller of The International Nickel Company of Canada, Limited, and the United States subsidiary in 1955. In 1960, he was named deputy comptroller of both companies.

He attended Pace College from 1938 to 1942, and from 1947 to 1949. During World War II, Mr. Gould served with the United States Navy.

Mr. Gould is a member of the Tax Executives Institute, Inc., the American Accounting Association and The Broad Street Club.

Born in Ireland, Mr. Gould became a citizen of the United States in 1933. He is married to the former Barbara Shannon. They have three sons and reside in Tenafly, New Jersey.

L. EDWARD GRUBB

Vice President
The International Nickel Company of Canada, Limited

and

Chairman and Managing Director
International Nickel Limited

and

Chairman
Henry Wiggin and Company Limited

L. Edward Grubb was elected vice president of The International Nickel Company of Canada, Limited and named chairman of the company's United Kingdom subsidiary, International Nickel Limited, in October 1968. He has been managing director of International Nickel Limited since November 1967 and chairman of Henry Wiggin and Company Limited since January 1968.

Mr. Grubb joined the International Nickel organization in 1934, and was general superintendent of the company's Bayonne Works in New Jersey from 1942 until 1953, when he was appointed general superintendent of the Huntington Works, the company's rolling mill in West Virginia.

In 1957 he was elected assistant vice president of The International Nickel Company, Inc., at which time he was transferre to New York and placed in charge of labor relations at all the company's United States plants. One year later he was appointed general sales manager of the Huntington Alloy Products Division and was elected vice president-sales for that division in May 1960. In December 1961 Mr. Grubb was named vice president of The International Nickel Company, Inc., with responsibility for primary nickel commercial activities in the United States. It was shortly after his election in 1964 as an assistant vice president of the parent company that he was transferred to Europe as managing director of Henry Wiggin, and as a director of International Nickel Limited.

He is a director of Impala Platinum (Pty) Limited in South Africa, a company in which International Nickel has a 10 per cent interest.

Mr. Grubb attended Wesleyan University, Middletown, Connecticut. He is a member of the Society of Automotive Engineers (U.S.), the American Iron and Steel Institute, the American Society for Metals, the American Institute of Mining, Metallurgical and Petroleum Engineers, and the British Iron and Steel Institute and the Institute of Metals (U.K.).

Mr. Grubb is a member of the New York Yacht Club, Union League Club and India House, all of New York; Baltusrol Golf Club in New Jersey; and St. James' Club, London.

JOHN OLIVER HITCHCOCK, B.Sc.

Vice President
The International Nickel Company of Canada, Limited
The International Nickel Company, Inc.

Director
International Nickel Limited

Mr. Hitchcock was elected vice president-international marketing of The International Nickel Company of Canada, Limited in 1967. At the same time he was elected vice president of The International Nickel Company, Inc.

Mr. Hitchcock was appointed managing director of International Nickel Limited and deputy chairman of Henry Wiggin and Company Limited in 1960, posts he relinquished in November 1967. He was elected assistant vice president of The International Nickel Company of Canada, Limited in 1961. Mr. Hitchcock is also a director of International Nickel Benelux S.A., International Nickel France S.A., International Nickel Iberica Limited, and International Nickel Services (U.K.) Limited.

His association with International Nickel began in 1927 when he joined the Development and Research Department of the company. He subsequently played an important role in the development of the Nimonic* series of alloys which made possible the development of the jet engine, and in the construction of the new Wiggin works at Hereford built in the early 1950s to produce these alloys.

He served as technical adviser to Non-Ferrous Metals Control of the Ministry of Supply during World War II. In 1943 he acted for the Combined Raw Materials Board in Washington. In 1946 he became personal assistant to the managing director of Henry Wiggin and was appointed assistant managing director of this company four years later. He was elected to the board of directors of International Nickel Limited in 1955 and was appointed sales director. Mr. Hitchcock is also a director of Ametalco Limited.

*Trademark

A graduate of the University of London, Mr. Hitchcock is a Fellow of the Institution of Metallurgists, and member of the Institution of Mining and Metallurgy, Institute of Metals and The Iron and Steel Institute. He is a Fellow of the Royal Aeronautical Society, a member of the National Liberal Club, London; The Canadian Club of New York, Inc., and India House, of New York.

Born in Wallington, England, Mr. Hitchcock is married to the former Marjorie Louise Tolley. They reside in New York City.

WILLIAM F. KENNEDY

Secretary
The International Nickel Company of Canada, Limited
The International Nickel Company, Inc.

William F. Kennedy has been secretary of The International Nickel Company of Canada, Limited since May 1952, and secretary of its United States subsidiary since March 1957. He is also a director and member of the executive committee of The International Nickel Company, Inc. and a director of Ajax Petroleum Company, Limited, Compania Centram, S.A., Inter-American Exploration Company, Limited and International Nickel S.A. (Proprietary) Limited.

Mr. Kennedy joined the International Nickel organization in May 1945 as assistant secretary and general solicitor of the parent company and its United States subsidiary. Upon his election as secretary of The International Nickel Company, Inc. in 1957, he relinquished his duties as general solicitor of the two companies. Before joining International Nickel, Mr. Kennedy was associated with Sullivan & Cromwell, the company's general counsel, for 15 years.

After graduating from the University of Pennsylvania in 1926 with a Bachelor of Arts degree, Mr. Kennedy received a Bachelor of Laws degree in 1929 from the University of Pennsylvania Law School. From 1929 to 1930, Mr. Kennedy studied under the Gowen Fellowship at the University of Pennsylvania. He is a member of Phi Beta Kappa Society and the Order of the Coif.

Mr. Kennedy is a member of the American Bar Association, New York State Bar Association and New York City Bar Association. He is also a member of the Mining and Metallurgical Society of America, and the Mining Club, University Club and Lunch Club of New York.

He is married to the former Ruth Bennett Maris, and they reside in New York.

JOHN A. MARSH

Vice President
The International Nickel Company of Canada, Limited

and

Executive Vice President
The International Nickel Company, Inc.

and

President
Huntington Alloy Products Division
The International Nickel Company, Inc.

John A. Marsh has been vice president of The International Nickel Company of Canada, Limited since April 1964 and executive vice president of the company's United States subsidiary, The International Nickel Company, Inc., since December 1966. He has been president of the latter company's Huntington Alloy Products Division since May 1960. He is also a director and member of the executive committee of The International Nickel Company, Inc. and chairman of Nickel Alloy International S. A.

Prior to his present positions, Mr. Marsh had been vice president of The International Nickel Company, Inc. since 1953, and manager of the company's Huntington Alloy Products Division since 1958. From 1936 until his appointment as assistant vice president of the United States subsidiary in 1952, Mr. Marsh held positions of increasing responsibility at the company's Huntington, West Virginia, and former Bayonne, New Jersey, plants. He joined the International Nickel organization in 1928 as a laboratory assistant at the Huntington Works.

Mr. Marsh received a Bachelor of Science degree from the University of Michigan in 1928. He is a member of the American Society of Mining, Metallurgical and Petroleum Engineers and American Iron and Steel Institute. Mr. Marsh is also a member of the City Midday Club and Broad Street Club, both of New York City; the Echo Lake Country Club and Baltusrol Golf Club in New Jersey; and Royal Poinciana Golf Club in Florida.

Mr. Marsh is married to the former Christine Maloney. They have one daughter and two grandchildren. Mr. and Mrs. Marsh reside in Westfield, New Jersey.

JOHN McCREEDY

Vice President
General Manager, Manitoba Division
The International Nickel Company of Canada, Limited

John McCreedy has been vice president of The International Nickel Company of Canada, Limited since February 1970. Prior to his present position, he had been assistant vice president since January 1969, and general manager of the Manitoba Division since 1967.

He joined International Nickel at Copper Cliff, Ontario, in 1949 as a mine efficiency engineer at Frood mine. A year later he was appointed production engineer in Copper Cliff and in 1953 became shift boss at Creighton mine. He transferred to the Levack mine in 1954, serving as a safety engineer, divisional foreman and general foreman.

In 1959 Mr. McCreedy was appointed assistant to the superintendent of mines and one year later assistant to the manager of mines. He became superintendent of mines for the Ontario Division in 1962 and division general manager (Manitoba) in 1967.

Before joining International Nickel, Mr. McCreedy was a professional hockey player with the Toronto Maple Leafs of the National Hockey League. From 1942 to 1945 he served in the Royal Canadian Air Force, where he attained the rank of flying officer and was a flying instructor in the British Empire Air Training Plan.

Mr. McCreedy received a Bachelor of Applied Science degree in mining from the University of Toronto in 1949. He is the author of several published articles and technical papers dealing with mining.

Mr. McCreedy is a member of Association of Professional Engineers of Ontario, Canadian Institute of Mining and Metallurgy and American Institute of Mining, Metallurgical and Petroleum Engineers.

He is also a member of the Manitoba Club, Winnipeg; Toronto Golf Club, and Idylwylde Gold and Country Club, Sudbury. Residing in Thompson, Mr. McCreedy is married to the former Ila Elizabeth Maxwell. They have one daughter.

FELIX M. A. NOBLET

Treasurer
The International Nickel Company of Canada, Limited
The International Nickel Company, Inc.

Felix M. A. Noblet has been treasurer of The International Nickel Company of Canada, Limited and its United States subsidiary, The International Nickel Company, Inc., since April 1954. He is a director and a member of the executive committee of The International Nickel Company, Inc., and treasurer of a number of International Nickel subsidiaries. Mr. Noblet joined International Nickel in September 1942 as assistant treasurer, and the same year was elected assistant secretary of the parent company, as well as assistant treasurer and assistant secretary of the United States subsidiary.

Mr. Noblet, a Canadian, received his early business training in Canadian banking. Before joining International Nickel, he had been associated with the Bank of Montreal in various capacities for 15 years, and from 1936 to 1942 he was assistant to the general manager. From 1925 to 1928, Mr. Noblet was employed by Canadian Pacific Steamships, Limited.

A director and past president of the Canadian Society of New York, he is also a member of India House and the Canadian Club of New York; the Canadian Club, Royal Canadian Yacht Club and the York Club of Toronto; and the Rideau Club of Ottawa.

Mr. Noblet, who was born in Turkey, is a Canadian citizen. He is married to the former Mary Jean Cahall Colegrove. They have five children and reside in Darien, Connecticut.

JOHN H. PAGE

Assistant to the Chairman
The International Nickel Company of Canada, Limited

and

Vice President
The International Nickel Company, Inc.

John H. Page has been assistant to the chairman of The International Nickel Company of Canada, Limited since January 1969, and vice president of its United States subsidiary, The International Nickel Company, Inc., since December 1966. Mr. Page joined International Nickel in September 1965 as special assistant to the chairman.

For four years prior to joining International Nickel, Mr. Page was executive vice president of the Free Europe Committee, Inc. From 1946 to 1961 he held various management and public relations positions in the Bell Telephone organization, resigning in 1961 as vice president of the Pacific Northwest Bell Telephone Company.

Mr. Page received a Bachelor of Science degree from Harvard University in 1942. He is a director of the International Development Foundation; a member of the Council on Foreign Relations; a vice president of The American Research Hospital in Poland, Inc.; a director of the Huntington Hospital in Huntington, Long Island; and a member of the Visiting Committee for the Press of Case Western Reserve University.

Born in New York, Mr. Page is married to the former Susan Simonds. They have four children and reside in Huntington, Long Island.

HARRY (HENRY) W. PETERSON

Vice President
The International Nickel Company of Canada, Limited

and

President
International Nickel Australia Limited

and

Managing Director
P.T. International Nickel Indonesia

Harry W. Peterson has been vice president of The International Nickel Company of Canada, Limited, president of International Nickel Australia Limited and managing director of P.T. International Nickel Indonesia since September 1969.

Prior to his present positions, Mr. Peterson had been assistant vice president of The International Nickel Company of Canada, Limited since 1967. He was general manager of the company's Manitoba Division from 1965 to 1967, when he transferred to the New York office. He had been assistant general manager of the Manitoba Division since 1962. Mr. Peterson joined International Nickel at the company's Murray mine in Ontario in 1944.

Born in Grenfell, Saskatchewan, Mr. Peterson received a B.A. Sc. degree in mining engineering from the University of Toronto in 1944.

He is a member of the Canadian Institute of Mining and Metallurgy and the American Institute of Mining Engineers.

Mr. Peterson is married to the former Phyllis Dickson. They have two daughters and reside in Sydney, Australia.

JOHN A. PIGOTT

Vice President
Division General Manager
Ontario Division
The International Nickel Company of Canada, Limited

John A. Pigott has been vice president of The International Nickel Company of Canada, Limited since February 1970 and division general manager (Ontario) since 1965.

Prior to his present position as vice president, Mr. Pigott had been assistant vice president since 1967. He joined International Nickel in the Mines Engineering Department at Copper Cliff, Ontario, in 1940, becoming mines production engineer in 1946. In 1950 he was appointed divisional foreman at Creighton mine, in 1951 general foreman at the mine, and in 1954 underground superintendent at Creighton.

After having served briefly as assistant superintendent of Frood-Stobie mine, in 1957 Mr. Pigott was named assistant superintendent of mines of the Ontario Division. In 1958 he became superintendent, and four years later was appointed assistant general manager of the Ontario Division.

He received a Bachelor of Science degree in mining engineering from Queen's University, Kingston, Ontario, in 1940. He is a member of the Canadian Institute of Mining and Metallurgy and American Institue of Mining, Metallurgical and Petroleum Engineers.

DEAN D. RAMSTAD

Vice President
The International Nickel Company of Canada, Limited
The International Nickel Company, Inc.

Dean D. Ramstad has been vice president of The International Nickel Company of Canada, Limited since February 1970, and vice president of The International Nickel Company, Inc. since 1966. He is also assistant secretary of both companies.

Mr. Ramstad was elected assistant vice president of both the parent company and its United States subsidiary in 1963. He joined The International Nickel Company, Inc. in 1957 as assistant secretary and as a member of the general solicitor's staff. Before joining International Nickel, he was an attorney with the firm of Sullivan & Cromwell in New York.

Mr. Ramstad graduated from the University of Minnesota, receiving a Bachelor of Arts degree in economics in 1944 and a Bachelor of Laws degree in 1949. He was awarded the Order of the Coif at the university in 1950. He is a member of the American Bar Association.

Born in Minneapolis, Minnesota, Mr. Ramstad is married to the former Marion McKinney. They have one daughter and reside in New York City.

LOUIS S. RENZONI

Vice President-Special Technical Projects
The International Nickel Company of Canada, Limited

Louis S. Renzoni has been vice president-special technical projects of The International Nickel Company of Canada, Limited since December 1969. Prior to his present appointment he had been vice president-process research since July 1968.

Mr. Renzoni had been vice president of the company since 1967 and manager of process research-Canada since 1960. He had been assistant vice president of the company since 1964. In 1960 he was transferred from Copper Cliff, where he had been superintendent of research since 1956, to the company's offices in Toronto. He joined International Nickel in 1937 as a research chemist at Port Colborne, Ontario.

He received a Bachelor of Science degree in 1935 and a Master of Science degree in 1936 from Queen's University, Kingston, Ontario. In May 1969 he received the honorary degree of Doctor of Science from Queen's University.

Mr. Renzoni is a member of the American Institute of Mining, Metallurgical and Petroleum Engineers and the American Chemical Society, as well as the Canadian Institute of Mining and Metallurgy. He is also a Fellow of the American Association for the Advancement of Science and the Association of Professional Engineers of Ontario.

The author of many papers and articles on metallurgy, he has been granted patents on extractive processes in nickel metallurgy. In 1960 and again in 1963, Mr. Renzoni received the Gold Medal Award of the Extractive Metallurgy Division of the American Institute of Mining, Metallurgical and Petroleum Engineers. In 1964 Mr. Renzoni was recipient of the Airey Award presented by The Metallurgy Division of the Canadian Institute of Mining and Metallurgy for outstanding contribution to metallurgy in Canada. In 1968 he received the R. S. Jane Memorial Lecture Award of The Chemical Institute of Canada for exceptional achievement in chemical engineering.

He is a member of the Engineers Club of Toronto, The Port Colborne Club, and the Copper Cliff Club.

Born in Copper Cliff, Ontario, Mr. Renzoni is married to the former Germaine DeGuire. They have four children and reside in Willowdale, Ontario.

WILLIAM STEVEN

Vice President, Process Research & Technology
The International Nickel Company of Canada, Limited

and

Vice President
The International Nickel Company, Inc.

William Steven has been vice president, process research and technology of The International Nickel Company of Canada, Limited since December 1969, and vice president of its United States subsidiary, The International Nickel Company, Inc., since 1966. He had been vice president-process technology and product development since 1968.

Dr. Steven joined The International Nickel Company, Inc. in 1959 as director of research and assistant vice president, after an association of 13 years with the parent company's United Kingdom subsidiary. He was named assistant vice president of the parent company in 1965.

He attended the Royal College of Science and Technology, Glasgow, Scotland, where he received a Bachelor of Science degree in 1939 and a Doctor of Philosophy degree in 1942. He was awarded the Blyth Memorial Prize in Natural Philosophy in 1936 and the Walter Duncan Research Scholarship in 1939.

The author of many technical papers on steels and cast iron, Dr. Steven is a Fellow of the Institution of Metallurgists in the United Kingdom. He is a member of the American Society for Metals; Institute of Metals; Iron and Steel Institute; American Institute of Mining, Metallurgical and Petroleum Engineers; and the Canadian Institute of Mining and Metallurgy.

He is also a member of the Engineers' Club and City Midday Club in New York and the Engineers' Club and Royal Canadian Yacht Club in Toronto.

Born in Glasgow, Dr. Steven is married to the former Margaret Hutchison. They have a son and reside in Toronto.

ASHBY McC. SUTHERLAND

Vice President
The International Nickel Company of Canada, Limited

and

Vice President
The International Nickel Company, Inc.

Ashby McC. Sutherland has been vice president of The International Nickel Company of Canada, Limited since February 1970 and vice president of The International Nickel Company, Inc. since 1966. Prior to his present position as vice president of the parent company, he had been assistant to the chairman-law since 1966. He also held the title of chief legal officer of the United States subsidiary from 1966 to February 1970, and previously had been general solicitor of both companies since 1957. He has been assistant secretary of the parent company since 1956, and of the United States subsidiary since 1955. Mr. Sutherland joined the International Nickel organization in 1953.

Mr. Sutherland received a Bachelor of Arts degree in economics in 1942 from the University of the South, Sewanee, Tennessee; an Industrial Administrator degree from Harvard Graduate School of Business Administration in 1943, and a Bachelor of Laws degree from Harvard Law School in 1949. He is a trustee of The University of the South. He is a member of the American Society of International Law, American Bar Association, New York State Bar Association and Association of the Bar of the City of New York.

He is also a member of the Harvard Club, Knickerbrocker Club and Lunch Club, all of New York City; the International Club of Washington, D.C.; and the Waccabuc Country Club, Waccabuc, New York.

Born in San Antonio, Texas, Mr. Sutherland is married to the former Adair Ramsey. They have two children and, while at present temporarily reside in France, make their home in New York City.

H. FRANKLIN ZURBRIGG

Vice President, Exploration
The International Nickel Company of Canada, Limited

H. Franklin Zurbrigg has been vice president, exploration of The International Nickel Company of Canada, Limited since August 1968.

Prior to his present position, Mr. Zurbrigg had been vice president and director of exploration of The International Nickel Company of Canada, Limited since 1967. He had been assistant vice president and chief geologist since 1964. He joined the International Nickel organization in 1933 as a geologist at the company's mines at Copper Cliff, Ontario. He subsequently held positions of increasing responsibility, and in 1956 was named chief mines geologist of the Ontario Division.

Mr. Zurbrigg is president of Canadian Nickel Company Limited, and an officer of other subsidiaries which conduct International Nickel's worldwide exploration activities.

A graduate of Queen's University, Kingston, Ontario, Mr. Zurbrigg received a Bachelor of Science degree in 1931 and a Master of Science degree in 1933.

Mr. Zurbrigg is a fellow of the Geological Society of America and the Geological Association of Canada. He is a member of the Canadian Institute of Mining and Metallurgy; American Institute of Mining, Metallurgical and Petroleum Engineers; Mining and Metallurgical Society of America; and Society of Economic Geologists. He is also a member of the Association of Professional Engineers of Manitoba.

Mr. Zurbrigg is married to the former Helen McLean, and they reside in Mountainside, N.J. They have two children, both married.

CORPORATE HISTORY

The history of The International Nickel Company of Canada, Limited can be traced back to the discovery of nickel-bearing ores in the village of Orford, Quebec, more than 90 years ago.

In 1877, the Orford Nickel Company was formed to mine these ores. In 1881, that company -- then known as the Orford Nickel and Copper Company -- purchased land for a smelter at Constable Hook in Bayonne, New Jersey. Not long after, in 1883, engineers of the Canadian Pacific Railway, clearing the way for tracks, uncovered a deposit of nickel- and copper-rich ore in the vicinity of Sudbury, Ontario, and this led to the formation of the Canadian Copper Company in 1886. During the years that followed, the two companies reached an agreement under which Orford refined the Canadian Copper Company's ores.

In 1900, The Mond Nickel Company, Limited was formed to develop Sudbury ores for treatment in Great Britain. Several years earlier its founder, Dr. Ludwig Mond, had discovered and developed, in conjunction with chemist Carl Langer, the Mond carbonyl process for refining nickel.

By 1902, it was apparent to the Orford Copper Company (formerly Orford Nickel and Copper Company) and the Canadian Copper Company that one could not survive without the other. Furthermore, extensive expansion was necessary in both. As a result, the two companies and several smaller ones merged that year to form the International Nickel Company (incorporated in New Jersey).

In order to consolidate the new company's mining interests in Canada, The International Nickel Company of Canada, Limited was formed in 1916 as a subsidiary of the New Jersey company and, in 1928, became the parent company.

During the 1920's, The International Nickel Company of Canada, Limited and The Mond Nickel Company, Limited started mining operations on adjacent properties in the Sudbury Basin. These operations proved to lead to the same ore body, the Frood, one of the largest ever discovered. In order to effect a single long-term mining plan for the economic and sound development of the Frood mine, the two companies merged as of January 1, 1929.

Thereafter, the two major subsidiaries of The International Nickel Company of Canada, Limited were The International Nickel Company, Inc. in the United States and International Nickel Limited (formerly The Mond Nickel Company) in the United Kingdom.

INTERNATIONAL NICKEL
The International Nickel Company of Canada, Limited
Toronto, Ontario

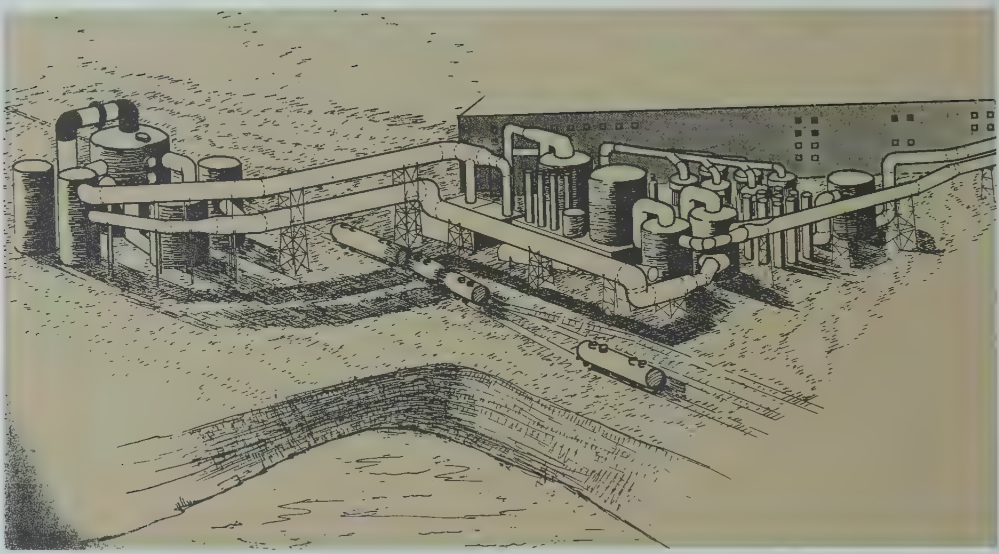
The International Nickel Company, Inc.,
New York, N.Y.

International Nickel Limited,
London, England

1970/3

INTERNATIONAL NICKEL

MAGAZINE



Technology And Pollution

The largest metallurgical gas-based sulphuric acid plant in the world — by late 1972 this sketch will have become a reality in Copper Cliff, Ontario. Financed entirely by International Nickel at a cost of more than $20 million, the new plant is part of a $40 million environmental control program being sponsored by Inco in the Sudbury area.

The technology represented by the new plant is a far cry from the practices of the early miners in Ontario. Open-air roasting of ore sixty years ago released vast quantities of sulphur directly into the air — with disastrous consequences for vegetation. These practices had ended by the 1920s but scars still remain as mute witness to the primitive technology of the early days. By contrast, the new plant will eliminate Inco's iron ore plant complex as a potential source of air pollution, not only from sulphur dioxide, but also from dust. All dust must be removed as a prerequisite to sulphuric acid production.

Canadian Industries Limited will build and operate the plant as an adjunct to CIL's present sulphuric acid complex. The fourth plant in the complex, the new installation will increase production of sulphuric acid from Inco smelter gases at Copper Cliff to a total of 5,000 tons per day.

A pioneer in Canada in the production of sulphuric acid and liquid sulphur dioxide from sulphur-bearing gases, CIL completed its first unit on the Inco site to manufacture acid from this raw material in 1930. Since that time, recovery of sulphur values from Inco's smelter gases has been expanded at an ever-increasing rate.

Manufacture of liquid sulphur dioxide began in 1952. Sulphuric acid operations were expanded in 1957, 1963, and 1967. The plant that came into production in 1967 with a capacity of 1,400 tons per day was at the time the largest of its kind in the world. The new plant will have a daily capacity of 2,300 tons.

INTERNATIONAL NICKEL

MAGAZINE

1970/3

The Cover

"More nickel...more nickel." Every year industrial and technological demands have become increasingly insistent, increasingly widespread. But these demands cannot be met simply by tuning up an assembly line. Ore in the earth must be found, mined, and processed. To produce more nickel, Inco has undertaken a $1.1 billion program, *Expansion in Canada* (page 2). This means more mines, more intensive use of existing mines, and new or expanded surface facilities, like the new mill at Thompson, Manitoba, shown on the cover in a dramatic fisheye view. With the bulk of the world's nickel reserves consisting of tropical laterites, however, "more nickel" also means *Solving the Lateritic Riddle* (page 10). The final results are not always supersonic planes or sleek new automobiles. "More nickel" can also make a skier's holiday safer (page 32).

Cover photograph by Horst Ehricht

This quarterly magazine of the worldwide International Nickel organization is published in Canadian, French, German, Italian, United Kingdom, and United States editions.
Special editions are published for Benelux, Spain, and South Africa with bound-in synopsis of the text in Dutch, Spanish, and Afrikaans.

INTERNATIONAL NICKEL MAGAZINE

Published by
The International Nickel Company of Canada, Limited
–producer of Inco Nickel, Copper, Cobalt, Iron Ore, Tellurium, Selenium, Sulphur, and Platinum, Palladium and other Precious Metals.

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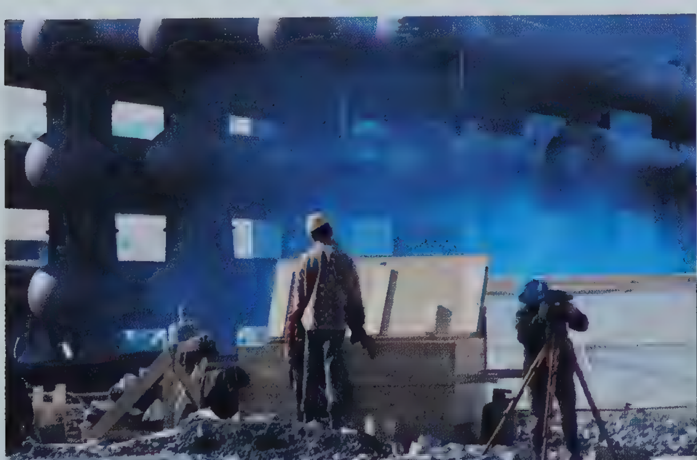
CANADA
Thompson
Shebandowan
Sudbury
UNITED STATES

Expansion in Canada

To increase its nickel production in Canada by 30 per cent to 600 million pounds in 1972, International Nickel launched in 1966 a vast expansion program estimated to cost over $1.1 billion. Inco's twelve producing mines in Canada—ten in Ontario and two in Manitoba—are currently scheduled to produce a daily total of about 100,000 tons of ore. Many of these mines are being expanded and new ones are being added, to increase daily capacity to 150,000 tons in 1972. Lower-grade ore requires mining 50 per cent more to increase nickel production by 30 per cent. This program represents International Nickel's short-term commitment to increase nickel production. Longer-term production increases will come for the most part from facilities being developed outside Canada.

On these pages are some of the tangible results of this program—mine expansion in the Sudbury District of Ontario and in the Thompson area of Manitoba, the opening of a new mine at Shebandowan in Ontario, and the expansion of surface facilities to handle increased ore production.

Soab Mine



Copper Cliff Nickel Refinery


Producing Mines
Mines Under Development
SUDBURY BASIN
SUDBURY
Scale of Miles
0
5
10

Sudbury

Frood-Stobie

Totten

In the Sudbury District of Ontario—an area that accounts for nearly 70 per cent of Inco's Canadian production—there are ten currently producing mines, including Frood-Stobie, *whose 30,000-ton daily capacity is the largest of any Inco mine, and* Maclennan, *producing 1,000 tons of ore per day. Three, including* Totten, *have come into production since 1966. The largest,* Copper Cliff North, *will have a daily capacity of some 8,000 tons of ore in 1971. Development work has been completed on another Sudbury mine:* Kirkwood's *capacity is about 1,500 tons.*

Three more mines are scheduled for production before completion of the expansion program in 1972. One of these is Copper Cliff South *where 6,000 tons of ore is the scheduled rate when full production begins. In addition, a number of existing mines are being expanded—including some of the new ones like* Totten, *from 500 to 1,100 tons per day.*

Kirkwood

Copper Cliff North

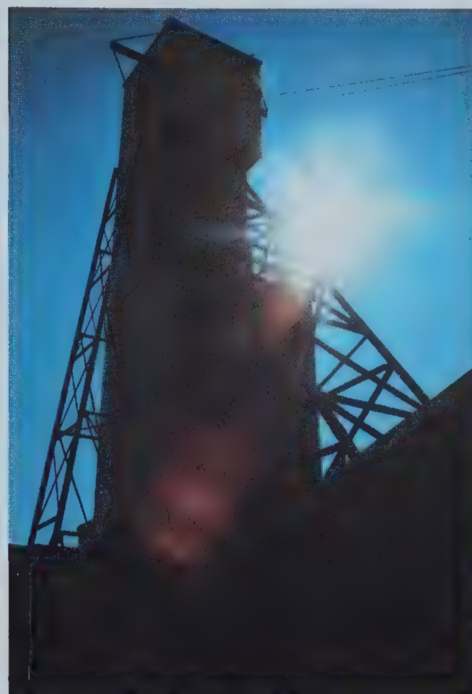
Copper Cliff South

Maclennan

Producing Mines
Mines Under Development
THOMPSON
Canadian National Railways Spur
Scale of Miles
0
10
20

Thompson

Pipe



Soab South

Birchtree

In the Thompson area of northern Manitoba—where only 14 years ago there was nothing but wilderness—two producing mines, Thompson and Birchtree, will be joined by Soab and Pipe. An open-pit and underground mine at Pipe will have a combined total daily capacity of some 16,000 tons of ore. Soab will produce at the rate of about 4,000 tons.

Pipe

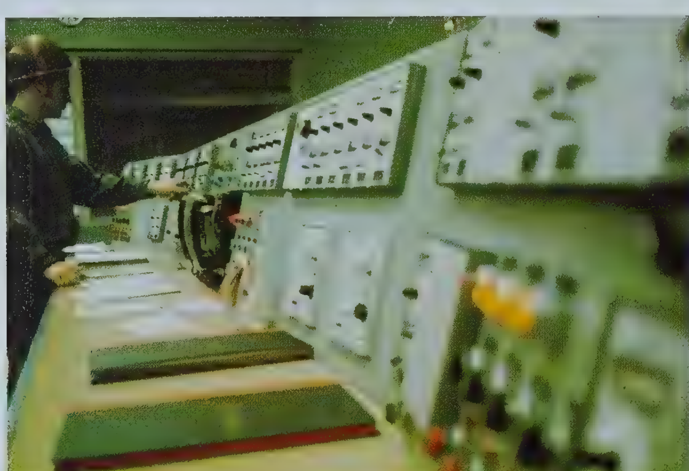
Shebandowan

Near Thunder Bay, in northwest Ontario, the Shebandowan mine and mill are being developed. In 1972, scheduled capacity will be 3,000 tons of ore daily.

Surface Facilities

Copper Cliff Nickel Refinery

Copper Cliff Iron Ore Recovery Plant



Frood-Stobie Mill

Electric Power

Advanced technology in mining and processing ore plays a vital role in Inco's expansion program.

One of several major surface facilities being built is the $80 million Clarabelle Mill, *whose new ore-crushing and concentrating machinery will replace obsolete equipment and provide additional capacity to handle ore from several new mines now under development.*

A new Inco-developed refinery process will be used at the Copper Cliff Nickel Refinery, *a highly automated facility with an annual capacity of 100 million pounds of nickel pellets and 25 million pounds of nickel powder. Nearby, the* Copper Cliff Iron Ore Recovery Plant *is undergoing major expansion.*

Among the plants built since the program began is the Frood-Stobie Mill. *With many operations under the exacting control of modern electronics, it has a capacity of 25,000 tons of ore a day. Capacity at the expanded* Thompson Mill *has been raised to 20,000 tons per day.*

New mines, plants, and equipment require more power and Inco has been adding electric power *distribution capacity, expanding existing substations and building new ones.*

Thompson Mill

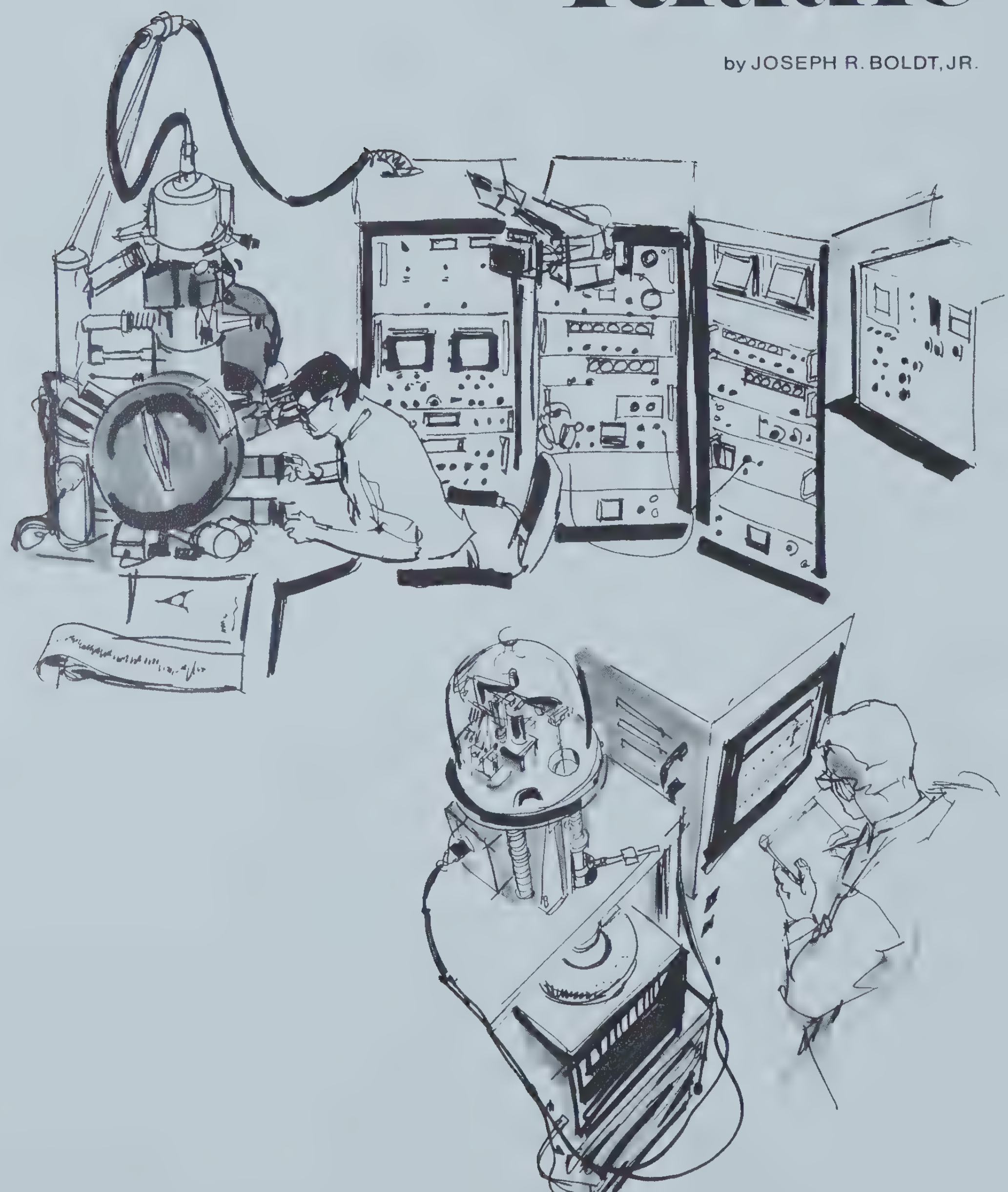
Photography by Horst Ehricht and John Cornell; maps by Bernard Gervey.

Clarabelle Mill

Major Surface Facilities
Major Surface Facilities Under Development
Copper Cliff
Mill
Smelter
Iron Ore Recovery Plant
Copper Refinery
Nickel Refinery
Levack Mill
SUDBURY BASIN
Frood-Stobie Mill
Clarabelle Mill
SUDBURY
Copper Cliff
Creighton Mill
Scale of Miles
0
5
10

Solving The Lateritic Riddle

by JOSEPH R. BOLDT, JR.



"Know your ore." At the J. Roy Gordon Research Laboratory, near Toronto, scientists utilize the electron microprobe (above), *thermal gravimetric analysis* (below), *and a variety of other methods to obtain an intimate understanding of the mineralogy and microstructure of each sample of lateritic ore they work on.*

Illustrations by Jack Hearne

The world's growing need for nickel, and the global effort to satisfy it, point up tantalizing anomalies. The metal is the fifth most common element in the earth—yet most of this terrestrial store is at depths beyond man's reach. It is relatively rare in the earth's crust, amounting only to about one one-hundredth of one per cent—yet other metals that are even rarer, such as copper, lead, and zinc, occur more commonly in commercial deposits. And yet—one more yet—scattered around the earth there lie, untouched, surface blankets of mineralization that have long been known to contain vast quantities of nickel.

These are nickel laterites, claylike deposits in which nickel occurs in oxide minerals—in contrast to the hard rock sulphide ores that have long made Canada the free world's chief source of the metal. Hundreds of thousands, even millions, of tons of nickel remain undeveloped in lateritic fields. Why, with a nickel shortage of grave consequence to the world's technology, have men not hastened to work these surface deposits lying ready to the bulldozer and the dragline, when other men labour more than a mile deep to the same purpose?

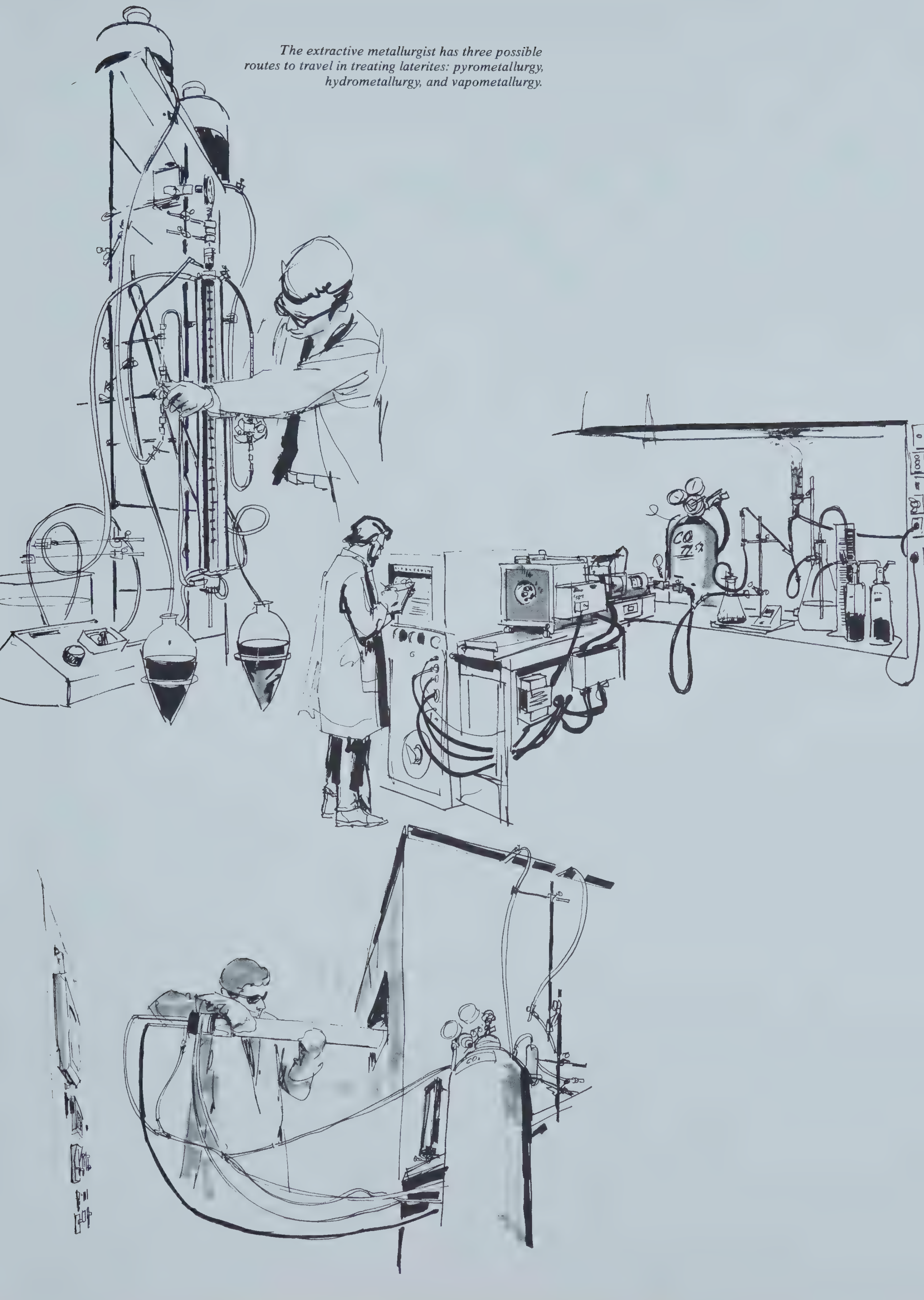
To answer is to explain why the art of obtaining nickel from oxide deposits continues as a major challenge to the extractive metallurgist — even after nearly a century of production from the famed oxide ores of New Caledonia, even after the more recent successes of other nickel laterite enterprises.

None have been more keenly aware of the challenge, or more active in confronting it, than the people of International Nickel. The enterprise that built leadership of the nickel industry on a mastery of sulphide ore technology has long known the day was coming when it would have to extend its competence to the oxide ores. Now events are revealing that the day has arrived—that 30 years of probing by Inco scientists into the perplexing problems that laterites pose for the extractive metallurgist are bearing important fruit.

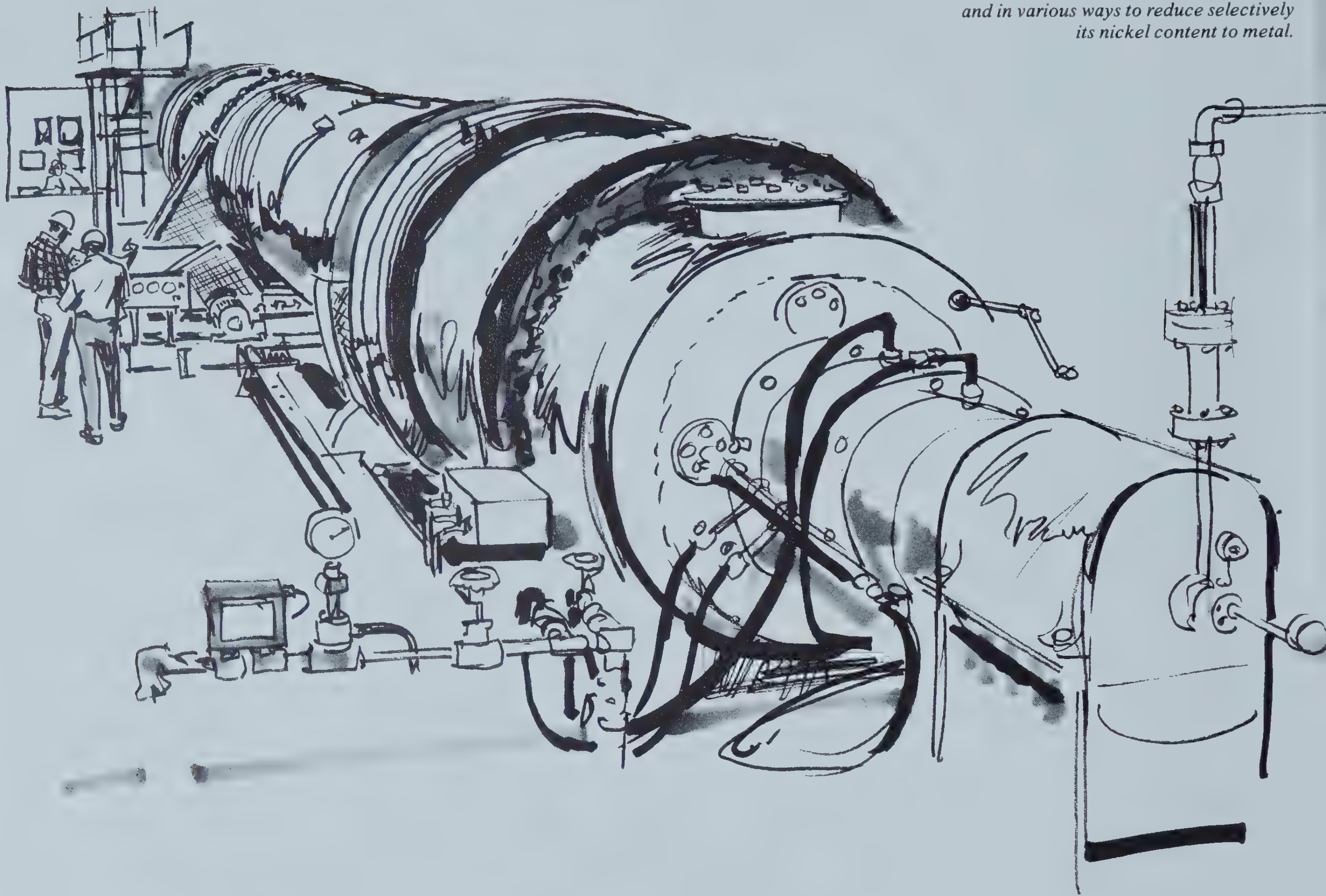
One such event took place in Paris early in July. Meeting with its French associates in Compagnie Française Industrielle et Minière du Pacifique (Cofimpac), Inco presented a feasibility study for the development of previously unexploited laterites in New Caledonia. It calls for a 481-million dollar undertaking to produce 100 million pounds of refined nickel annually by a process radically different from any hitherto employed to extract the metal from oxide ores.

The event is not an isolated one—nor, indeed, is the quest for extractive

The extractive metallurgist has three possible routes to travel in treating laterites: pyrometallurgy, hydrometallurgy, and vapometallurgy.



Pilot plant kiln at Research Station No. 2 at Port Colborne, Ontario. Inco is applying to lateritic processing knowledge gained as a pioneer in kiln technology. Kilns are employed to dry the ore and in various ways to reduce selectively its nickel content to metal.



breakthroughs limited to lateritic deposits. To satisfy the world's nickel hunger, the work on laterites goes forward in tandem with a vigorous research program to develop new sulphide ore technology, and so offset the decline in grade of the sulphide minerals now being mined. The sulphide program, which is reflected in the gamut of expansionist activity in Canadian nickel operations, is an indispensable means of increasing the nickel supply—but it is not enough. The hard fact is that if the burgeoning demand for the metal is to be fully met, the major part of the increase must come from the oxide ores.

Geography And Metallurgy

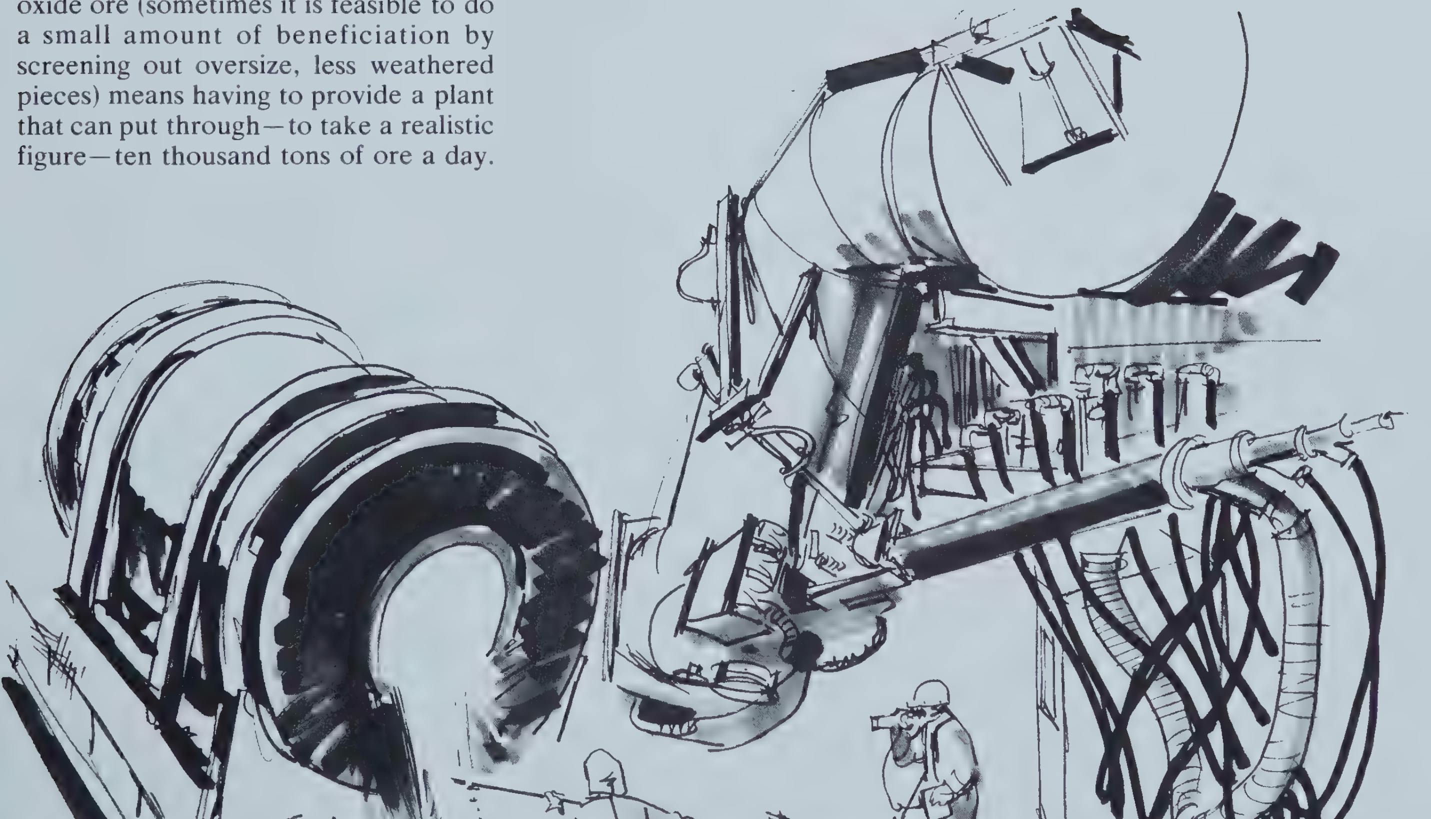
Nickel is among a small number of metals that under favourable conditions of geology and climate tend to be concentrated in the weathered clay-type surface deposits called laterites. Take a globe of the world, lop off the sections north of the Tropic of Cancer and south of the Tropic of Capricorn, and on the equatorial belt that remains one can locate most of these nickeliferous blankets. They occur in the tropics because warmth, moisture, and vegetation are prime factors promoting the laterization phenomena that create the nickel concentrations.

This accounts for a common difficulty in the commercial development of laterites, despite their surface accessibility. Since their tropical genesis tends to locate them in remote places, they are likely to be far from the parts of the world where the needs for nickel are centred, and where the materials for building and operating a plant are most economically available. They are not near readily tapped pools of engineers and production men, or a skilled labour force. Sometimes, indeed, they are remote from human habitat, necessitating the creation of entire communities with energy and service complexes.

But even if such factors of geography, distance, and paucity of resources did not exist, the central obstacle remains: the technology is fraught with difficulties. To begin with, all of the world's known high-iron laterites awaiting development are low in nickel grade—quite a different matter from the rich New Caledonia silicates that have been in production since the last century. This is all the more serious in the light

of the one factor that from an extractive treatment viewpoint sets the oxide ores apart: the metal is chemically disseminated throughout the material. Grind the ore into countless minute particles, and every particle contains nickel—hence every particle must be processed. This differs from hard rock sulphide ores which, when they are ground sufficiently fine, break down into particles of rock minerals and particles containing metal values. The ground ore can then be upgraded by using conventional beneficiation methods to segregate and discard the worthless rock particles. This gets rid of a substantial percentage of the ore before the start of extractive treatment, greatly reducing throughput costs of the operation.

The need to treat virtually all of an oxide ore (sometimes it is feasible to do a small amount of beneficiation by screening out oversize, less weathered pieces) means having to provide a plant that can put through—to take a realistic figure—ten thousand tons of ore a day.



The use of top-blown rotary converters with commercial oxygen to transform molten nickel sulphide to crude metal is a revolutionary Inco invention. The method, first used in sulphide ore extraction, will be applied in processing Guatemalan laterites.

This is intrinsically costly both in capital investment and operating costs. The accessibility of the deposits that makes mining relatively easy is an offsetting factor, but the prime compensatory need is for a large-scale continuous-flow extractive process.

Compounding the costs is the wetness of laterites. Nearly half their content is water, present either in free form or combined as part of the ore's lattice structure. In most processes a lot of heat energy must be expended just to dry the starting material.

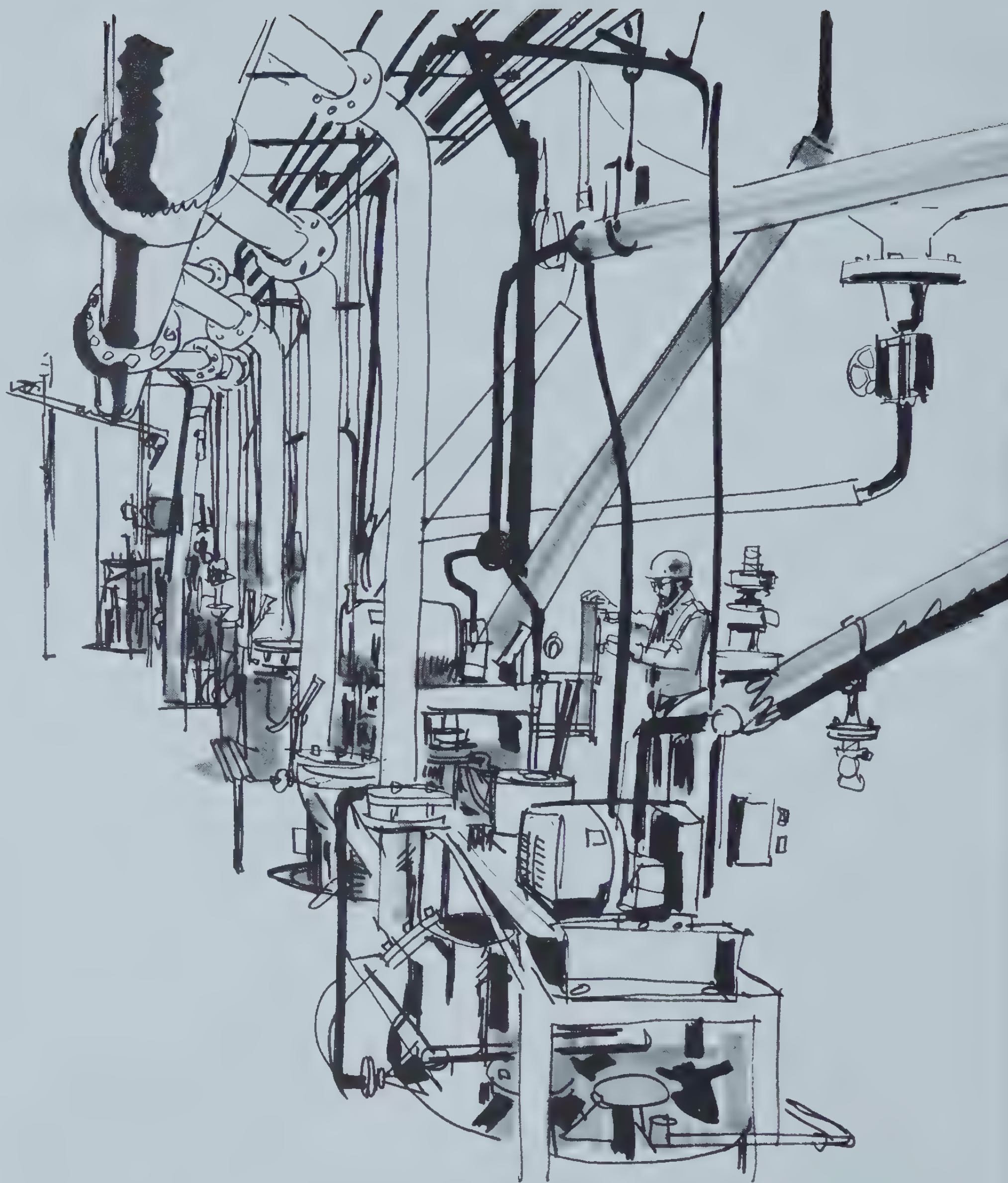
The metallurgy of oxide nickel ores is further complicated by the fact that their mineral structure and chemical composition vary with depth. The nearer the surface, the more iron they contain; the greater the depth, the more nickel and magnesium. In *nickeliferous limonite,* the high-iron type of ore, the oxide nickel is mainly in solid solution with the iron oxides. In *nickeliferous silicates,* nickel, iron, and cobalt are found in varying proportions, replacing part of the magnesium. In the silicates, nickel content tends to run higher than in limonite. Since the two ore types vary in composition and nickel mineralogy, their response to extractive techniques will vary. Strata of both types usually occur in any lateritic nickel deposit, with no clear line of demarcation. Sometimes the transition is extremely gradual. A basic decision usually required is whether to treat a material that is predominantly one type or the other, or to blend the two.

Further complications arise from other metals in the ore. Iron, although it is the principal metal present and may be treated as a co-product, is essentially a contaminant. Cobalt is often present, but whether it can be economically extracted in its own right is another difficult question. Chromium, when present, is a contaminant, since it cannot be extracted profitably.

The Lateritic Riddle

Thus every lateritic nickel deposit is an individual riddle—a particular combination of geological and chemical factors. Its extractive metallurgy is subject to geographic, technical, and economic influences that vary considerably from one deposit to another. That is why there are almost as many ways of treating nickel laterites as there are deposits being worked commercially. In any new lateritic situation, nothing less than a novel extractive process may solve that particular riddle.

A century's experience gathered by the French in treating New Caledonian silicates was of small use to Inco extractive metallurgists who developed and



Direct leaching processes have the advantage of not requiring that wet lateritic ores be dried before treatment. Port Colborne's Research Station No. 3 is equipped to test both atmospheric (above) *and pressure* (opposite) *leaching techniques.*

assessed the feasibility of different chemical processes for treating New Caledonian high-iron laterites that lie close by. In this instance it is not so much the mineralogical difference that is significant as the difference in grade. Even today, when their grade is down considerably from former times, the New Caledonian silicates are the world's richest nickel ores. Virtually all other nickel laterites, by contrast, are low in grade—a basic reason why they have remained undeveloped. Again, neither of the commercial leaching processes presently employed on low-grade nickel laterites provides a useful example for treating Inco's Guatemalan ores.

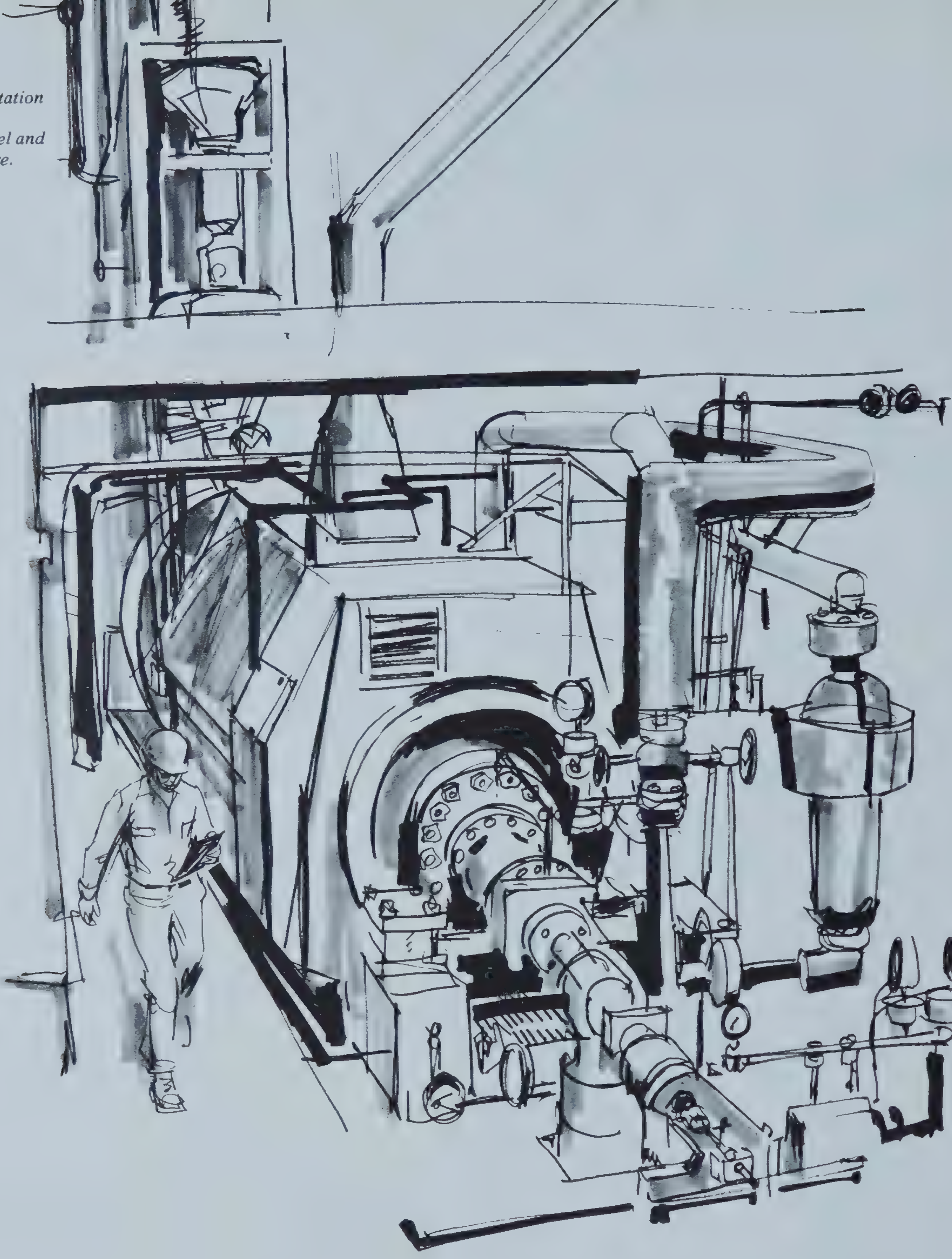
The Search

Inco's efforts to solve the lateritic riddle go back at least to 1939, when extractive experiments were carried out on silicate ores in the new research building at Copper Cliff. As early as 1946 a pilot plant employing an ammonia leach process on Venezuelan laterites was started up at Coniston, Ontario. The contemplated Venezuelan undertaking did not materialize, but there is a serendipity factor that often rewards industrial process research in unanticipated ways. The work on ammonia leaching led to the development of a chemical process for the recovery of nickel and iron from pyrrhotite. This iron-rich mineral common to sulphide ores is roasted to a nickeliferous oxide, selectively reduced, and leached. The products of the process are an acid-soluble nickel oxide powder and a high-grade iron ore. This operation transforms low-nickel pyrrhotite from a debit to a valued iron-nickel asset. With this background and experience Inco was able to further develop and adapt its ammonia leaching process to the lateritic ores to produce a high-grade nickel product.

Over the years Inco researchers have investigated all the established avenues for processing laterites, seeking new ways to utilize the working principles more efficiently, as well as searching diligently for new principles to apply. They have devoted much effort to proliferating and mastering the art of selective reduction of nickel relative to iron, as a pretreatment of the ore for a number of novel processes. They have developed several new pyrometallurgical techniques for upgrading final products from lateritic ores. In extensive leaching experiments, they have employed the conventional solvents and have tested others for the desired selectivity and economy.

Inevitably they have also travelled a radically different route of inquiry that is uniquely the company's province:

Carbonyl process volatilizer in Research Station No. 1. The selectivity of carbonyl-forming reactions makes it possible to extract nickel and iron as pure carbonyls directly from the ore.



vapometallurgy. For nearly three-quarters of a century, Inco's refinery at Clydach, Wales, has utilized the principle discovered by Alfred Langer and Ludwig Mond in 1889—that when carbon monoxide gas contacts active nickel, four molecules of the gas combine with one atom of the metal to form the gaseous compound nickel tetracarbonyl—and that if this gas is then heated, the carbonyl molecule decomposes back to metal and carbon monoxide. This remarkable affinity of gas and metal was bound to conjure up a dramatic concept: selectively reduce raw oxide ore to form nickel metal, and employ carbon monoxide to pluck out the nickel and deposit it free of impurities. Laboratory experiments at Copper Cliff in the early 1950s, followed up by a pilot plant operation at Clydach in 1953, confirmed the essential soundness of the concept.

The Critical Decade

For International Nickel, the 1960s were an historic decade in which an essentially Canadian company transformed itself into a, quite literally, worldwide enterprise. Within the three-year period starting in 1965 the company acquired large lateritic mining and development rights from the government of Guatemala, entered into an agreement with Indonesia to explore and develop lateritic deposits in a 25,000-square-mile area on the island of Sulawesi, and joined with French interests to develop extensive lateritic deposits in New Caledonia.

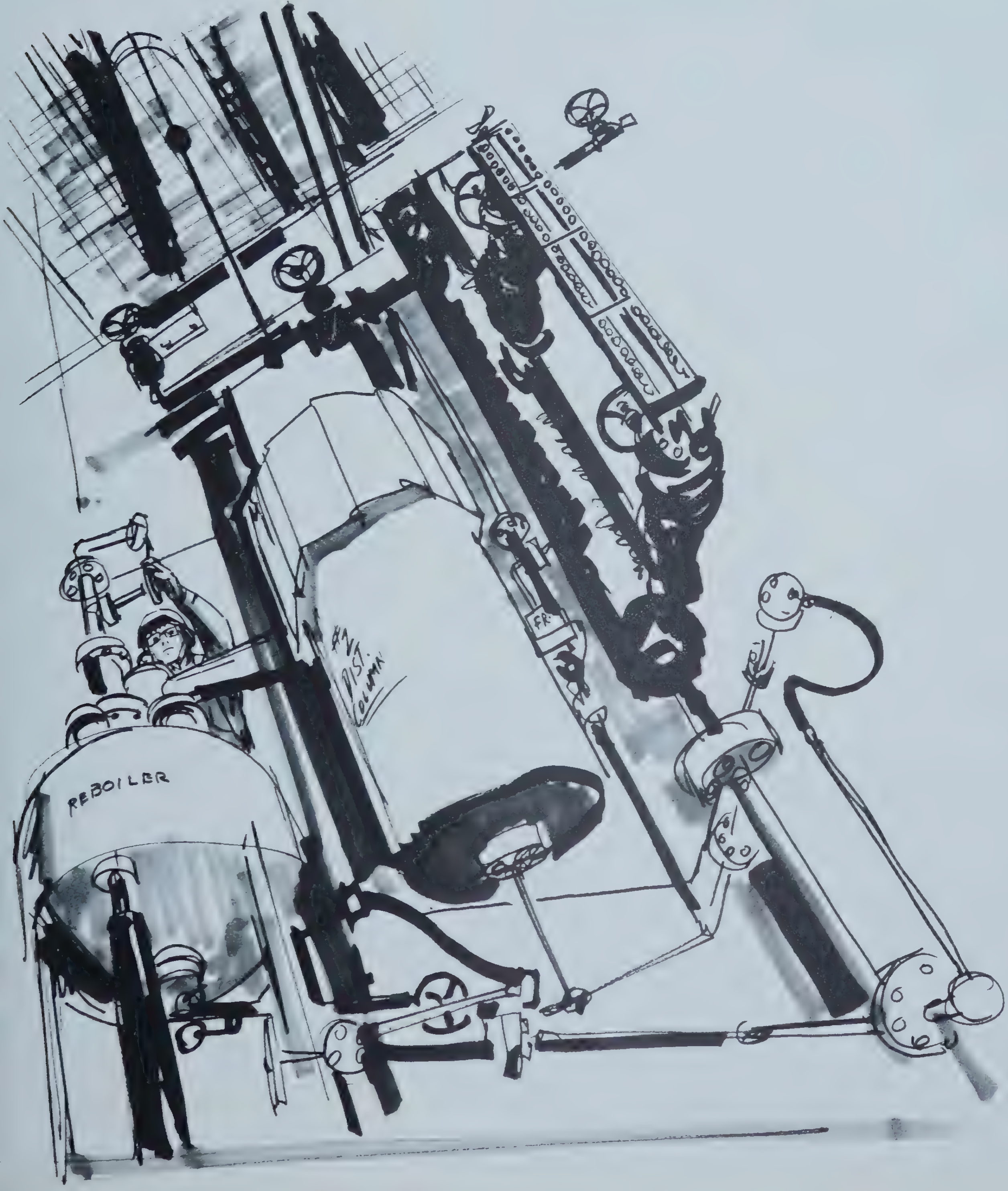
With a few pen strokes it committed itself to responsibility for hundreds of millions of tons of potential ores—all laterites—from which, conceivably, could come increases to the world's annual nickel supply totalling hundreds of millions of pounds. At the same time, important exploration and development work involving laterites went forward in Australia and the British Solomon Islands Protectorate.

During the 1960s, International Nickel created a $14 million extractive process research complex in Ontario—three research stations at Port Colborne and the J. Roy Gordon Research Laboratory at Sheridan Park. The research stations—one each for pyrometallurgy, vapometallurgy, and hydrometallurgy—are pilot plants capable of testing on a tonnage basis almost any process within the basic disciplines of the extractive metallurgist. With "process development teams" coordinating field work and research, the company is pursuing an all-out program to solve the lateritic riddle on three fronts—Latin America, the South Pacific, and Australia—and so take a giant stride toward ending the world nickel shortage.

Laboratory And Pilot Plant

The laboratory at Sheridan Park is a multi-million-dollar facility, housing modern scientific equipment that enables the staff to examine virtually any metallurgical technique for extracting nickel and its associated values from deposits anywhere in the world. Once an ore's chemistry and mineralogy are known, the desired products determined, and ancillary considerations defined, it is possible to eliminate from the list of potential processes all but the few that are economically competitive. The laboratory's target is high nickel extraction. A process deemed to have a commercial potential is run through the laboratory's "mini-plant" as a final test before it goes to the pilot plant.

It would be foolhardy, if not impossible, to go from the laboratory to production. Pilot plant testing of a proposed process on a tonnage basis is in-



Simple distillation techniques provide a separation of nickel and iron carbonyls.

Inco's modern pilot plant facilities are located at Port Colborne, Ontario.

dispensable. The transfer from laboratory to pilot plant is itself a scaling up 500 to 1,000 times, shifting from a batch to a continuous process under operating conditions that approximate those that will prevail in production.

A pilot plant is a classic example of a condition that is not a theory. "Every time we change ore," they tell you at Port Colborne, "we get surprised." This is where the engineers learn that a high-iron ore from one area will not settle in thickeners like a high-iron ore presumably just like it from another area, that a material reacts as it is supposed to chemically but sticks in the kiln while doing so, that a minor impurity that gave no trouble in the laboratory raises hob in a scaled-up situation.

Thus the pilot plant's function is to take a laboratory process and turn it into a commercial process. It produces only numbers, but from these are derived the parameters for the engineering design of the production plant. Here the scaling up is 100 to 500 times.

Some Solutions

Out of the laboratory-pilot plant gauntlet has come a novel pyrometallurgical process for Guatemala, employing a new invention for selective kiln reduction of the ore with simultaneous sulphiding, followed by electric furnace melting of the reduced charge, and upgrading to the desired degree by oxygen converting —a process step that the textbooks still say is impossible.

The Inco feasibility report to Cofimpac concluded that the most feasible process, from both a technical and economic point of view, for treating the ores available to Cofimpac is Inco's moderate pressure carbonyl process for laterities (ICPL). Raw ore is dried, selectively reduced, and continuously treated with carbon monoxide at seven atmospheres pressure to volatilize the nickel and a minor part of the iron as carbonyls. The nickel and iron carbonyls are then absorbed, separated by distillation, and decomposed to nickel pellets and iron granules.

Selection of the ICPL followed a comprehensive pilot-plant campaign to assess the relative merits of three competing processes when applied to ores available to Cofimpac. These were, in addition to the ICPL, the Inco Ammonia Leach Process, and the Inco Pressure Leach Process. Each is a novel process, incorporating inventions either not heretofore used on laterites or never before employed anywhere. From the technical point of view, all three processes investigated are feasible for treating these ores, but they have different capital requirements and profitability returns. Inco's evaluation of the three processes discloses that the ICPL is the most profitable for this particular project.

Once a month the process development teams for Guatemala, Australasia, and New Caledonia, each headed up by a process manager, meet in Toronto. They evaluate the laboratory and pilot plant findings, discuss ways to eliminate trouble spots, determine needs for new research, critique the conceptual design engineering, scan the cost sheets. If the minutes of the meetings make one paramount point, it is that in the extractive metallurgy of oxide ores there are many possible solutions. But arriving at these solutions is only half the task. At a given time and place, which is best? In the making of that hard decision lies the ultimate solution of the lateritic riddle.

With this article, Joseph R. Boldt marks the fifteenth year of a close association with International Nickel. A freelance writer specializing in industrial and documentary motion pictures, he is the author of many films dealing with Inco operations. *The Winning of Nickel*, a book written by Mr. Boldt under the direction of Paul Queneau, Consulting Engineer to the Chairman of The International Nickel Company of Canada, Limited, and sponsored by the company, has been called "one of the finest examples of lucid technical writing ever to be published."

SOME REALITIES OF POLLUTION

by LOUIS S. RENZONI

A "first" for Inco... growing grass and grain on sterile rock waste.

In a recent speech at the management session of the joint conference of the American Chemical Society and the Chemical Institute of Canada, Louis Renzoni addressed himself directly to the controversial problem of pollution. As Vice President, Special Technical Projects, of The International Nickel Company of Canada, Limited, he spoke with the special importance of direct involvement.

The extensive campaign to clean the environment and bequeath a better quality of life to future generations is a goal that deserves a high priority in the field of human endeavour. While we can argue the means of achieving the objective, the desirability of the end result cannot be disputed.

As in every popular movement, there has been an element of exaggeration. How often have we heard that mankind is polluting itself to death, that eco-catastrophe is just around the corner! That is overstating our predicament. On the other hand, the ramifications of pollution should not be reduced to understatement. There is concern in some sectors of the scientific community that we may be taxing the considerable self-regenerating abilities of the environment. We cannot continue to assault the purity of our air, water, and soil at an accelerating rate; we must reverse this trend and return the environment to a condition enjoyed by past generations.

Everyone must understand that so-called "zero" pollution is unattainable. Discharge of waste materials into the water, soil, and air has always been an unavoidable consequence of human activity. In the last quarter-century, the population explosion and the rising standard of living have combined to escalate pollution problems. Man has used technology to shape his consumption patterns; he can also use it to shape his environment. He will continue to use nature's treasures to improve his life, but now he must direct a greater portion of his energy and skill to intelligent use and protection of the environment.

Abatement of pollution, while mainly a technological problem, is not only the province of science. Any attempt to manage or control the environment also must involve the law, sociology, politics, and economics. Until the pollution battle is won, society's best course is to seek a healthy balance between production requirements and environmental protection through the law.

Sound legislation is important to the technical people who work within the framework of government regulations. Unfortunately, some contamination limits have been set without knowledge of their effect on the environment. For example, there is considerable misinformation about sulphur dioxide. It is easy to detect, and therefore gets blamed for many pollution problems in which it has only a small part. Dr. R. B. Sutherland of the Ontario Department of Health recently observed: "People are jumping to the erroneous conclusion that it's sulphur dioxide that is the hazardous chemical in pollution." He went on to point out that the amount of

sulphur dioxide in the air has no significance by itself, that it serves only as an indication of the overall level of pollution. Of course, its use as a pollution index is not unreasonable.

It has been variously reported that on a global basis some 80 per cent of the total amount of sulphur dioxide in the atmosphere comes from organic decay, or natural rot; that only about 6 per cent can be attributed to smelters, while power plants account for about 14 per cent. In dealing with sulphur dioxide emissions, we should also bear in mind that the average residence time for sulphur in the troposphere is estimated at about four days. Therefore, it follows that the obvious short-term requirement in the light of available technology is effective diffusion to harmless ground-level concentrations. There is no validity to the argument that the mass of sulphur dioxide emitted from a stack, rather than the concentration at ground level, is the only allowable factor in determining pollution.

We often see statements in the press to the effect that diffusion is not the solution to pollution. That makes easily digestible reading. But, like most broad generalizations, it has an element of truth without telling the full story. As far as sulphur dioxide is concerned, it's time the facts were stated bluntly and honestly. Effective diffusion is the solution to potentially harmful emissions. The public has placed its trust in the scientific community to explain and combat pollution, and it's gratifying that, at long last, there is a scientific backlash against misleading information about sulphur dioxide.

Before We Can Run

Public expectations tend to run ahead of technological ability in the pollution fight. As a result, in the early stages of this long battle, over-reaction must be moderated by good sense. Ontario Premier John Robarts warned recently that pollution cannot be controlled as quickly and easily as everyone would like without endangering industry and the standard of living. Nobody benefits if an industry is forced to dump money into a pollution abatement project that only creates new problems.

There is no standard approach to all pollution problems; each must be tackled individually. For example, diffusing a pollutant in a large urban centre can be a totally different problem than diffusing the same pollutant in a smaller community or in a rural setting. Location, meteorology, and topography are obvious considerations. Many pollution abatement projects undertaken by industries are in essentially non-productive facilities. To help allay the cost of these programs, industries are pressing for realistic tax incentives on new pollution control devices.

International Nickel keeps a close check on water systems: a technician testing water.

In seeking solutions and determining where money should be spent, it should be remembered that there is a difference between contamination and pollution. According to the World Health Organization, a contaminant becomes a pollutant when it affects man's physical and mental well-being. Both are undesirable. But, so long as a contaminant is not shown to be injurious to health or to the environment, is it not reasonable to give the financial resources to the scientists and technologists who are tackling pollution problems in an orderly, intelligent fashion? We have to walk before we can run.

Tallest In The World

Working within the limits imposed by technology and money, most industries are trying to do a creditable job of pollution control. As is well known, International Nickel gives high priority to environmental management. In the Sudbury area, we have undertaken a comprehensive program to provide air quality that will easily meet recently established Ontario criteria. The program involves the doubling of our sulphuric acid production capacity at the iron ore recovery plant complex to bring capacity to about 5,000 tons of 100 per cent acid per day. We are fully aware that a market for this quantity of acid will be difficult to find. This project, being undertaken coincidentally with expansion of the iron ore recovery plant, is scheduled for completion by the end of 1972. It will eliminate the complex as a potential source of air pollution, not only from sulphur dioxide, but also from dust, which must be removed from the gas prior to sulphuric acid production. The tail gas from this acid system will be emitted from the existing 637-foot stack, a height unprecedented for this type of gas. At this stage, Inco will be fixing about 40 per cent of the total sulphur dioxide generated at Copper Cliff.

At the Copper Cliff smelter, the three existing stacks — two at 500 feet and the other at 350 feet — will be retired and replaced by a single 1,250-foot stack, the tallest in the world. Two additional

electrostatic precipitators will be installed and existing precipitators will be expanded. From this single point, the dilute, electrostatically treated smelter gases will rise at a velocity, temperature, and mass consistent with proper diffusion. Completion of this project is scheduled for the end of 1971. When these projects are completed in 1972, the Copper Cliff operations will not harm *any* vegetation—even under the worst conditions for diffusion. This program is the only practical approach within the bounds of proven technology.

Looking further ahead, International Nickel is currently developing a method of processing sulphide ores that does not involve the generation of sulphur dioxide. We are not alone in this field. Already, methods have been evolved, but they have serious limitations. Therefore we have to approach our diffusion problems realistically—and there are also limitations to our available technology. For example, there is no proven process for the economic concentration and recovery of sulphur values from weak off-gases. This was a principal finding of a study prepared last year for the United States Department of Health, Education and Welfare.

International Nickel gives high priority to environmental management: the Garson mine underground pollution control centre.

For The Common Benefit

Quality control of watercourses in some sectors of our economy is an equally important and costly undertaking. I would like to restrict this discussion to the problems that arise from mining sulphide ores. The main areas of concern stem from oxidization of sulphides in contact with groundwater—which results in acidic water containing dissolved metals, seepage from disposal areas, and spills—or overflows—as a result of mechanical failure or human error. Most problems can be avoided by intelligent planning and sound management.

International Nickel keeps a close check on water systems and, where necessary, devises new and more efficient techniques to meet expanding production requirements. The company's Sudbury operations use tremendous volumes of process water. At 9 townsites, 14 mines, and 8 plants throughout the district, more than 33 million gallons of fresh water are consumed daily. In the same area, more than 100 million gallons of water are re-used every day. Development of water recirculation systems has resulted in a reduction of freshwater requirements in the past five years, despite a great expansion in operations. Experience and new technology have enabled Inco to re-use greater amounts of water without any adverse effect on mill operation and metallurgical control.

In order to determine the effectiveness of International Nickel's water management procedures, waste water is monitored prior to discharge into natural watercourses, and the watercourses themselves are monitored upstream and downstream from the point of discharge. Results of the monitoring programs are made available to the appropriate government agencies, either by arrangement or upon request.

For the most part, the mining industry in North America has a fine record of combating water pollution and of managing water for the common benefit. We need large amounts of water, and we respect it as an important natural resource. Certain other industries with more complex water pollution problems still have a long way to go to meet their objectives. Many municipalities and farming operations continue to be sources of damaging water pollution. The combined effect of all pollutants from every source has created many intolerable situations.

Keeping Them Clean

In the long run, everyone must share the responsibility of cleaning up our fouled waters and keeping them clean. We all pollute, directly or indirectly, because we all use water, dispose of wastes, and consume the products of industries that require more water every year to sustain their increased production. It's estimated that the water requirements of the United States in the year 2000—for all uses—will be three times what they were in 1960.

Some water bodies, such as Lake Erie, may have been permanently damaged. Others can be cleaned up. Beyond that, we must take precautions to prevent pollution of lakes and streams that, so far, have been spared in man's reckless pursuit of progress.

The Canada Water Act and Ottawa's extraordinary measures to safeguard the arctic waters are indications of deep

concern at the highest level in the nation. International cooperation, such as the Canada-U.S. commission on the Great Lakes, also recognizes the magnitude of the problem. Even the United Nations and its various agencies have offered their resources and expertise in the pollution fight.

The Underlying Issue

I think it's important not to lose sight of the underlying issue in the pollution fight — general improvement in the quality of life. This is a very broad objective, and covers not only the obvious and dangerous pollution of the air and water, but the ubiquitous pollutions such as sheer ugliness and noise. Land and wildlife conservation also must be part of the overall objective.

Not only is smog unhealthy, it's ugly. Not only are polluted lakes dying, they are becoming unsightly. Despoiled lands pockmark the earth. Just after the turn of the century, the mining industry was responsible for despoiling land in the Sudbury area when it was common practice to roast ores in the open. But that was a period when basic economic needs — the development of new industries and the creation of new jobs — were paramount. Nobody knew or cared about the ravages of pollution; the availability of virgin land seemed limitless. That era ended in the 1920s with the first enclosed roasting furnaces and tall chimneys, but the damage was already done and the ugly legacy of open roasting remains with us today.

The erosion of tailings over the years added a new, ugly dimension to the barren, non-productive terrain. International Nickel tackled that problem some 40 years ago, but only in the past decade have we been successful in stabilizing the tailings by growing grass and grain on the sterile rock waste. That success was a "first" for Inco in the Western Hemisphere. Now, the dream of our agriculturalists is to grow vegetation — grass, even trees — on the bleak, barren rock that has made the Sudbury area famous — or infamous — for its so-called lunar landscape.

Raw Materials At A Premium

While industries have a responsibility to include aesthetic considerations in their development programs, they are not the only ones who have despoiled the land. The mounting mass of solid waste — most of it household refuse — is the result of the push by a growing population toward an ever higher standard of living. North Americans create more garbage than any other people on earth. Much of it ends up in unsightly, inadequate dumps, or simply as litter. We indiscriminately discard a growing amount of bottles, tins, old auto bodies, and other scrap metal. Almost every consumer item is elaborately packaged, and often the container is greater in bulk than the item it encloses.

We would be well advised to heed the old adage "waste not, want not," because the day is fast approaching when raw materials will be at a premium. Our natural resources are not limitless, and consumer demands are depleting nature's treasures at an alarming rate.

Part of the answer to the resource conservation dilemma is greater utilization of mined ores. International Nickel, for example, recovers not only nickel but 14 other important elements from

its Sudbury ores, and advances in process technology have enabled Inco to mine lower grade ores. High recovery of minerals is also an important factor in the pollution fight because less material is discharged as waste.

The answers to all the problems will not be found easily, but it is evident that solutions will have to be related to value judgments. If our personal concern is to be translated into action, we may have to be prepared to forego certain accepted aspects of our way of life. First, we must accept the new fact that no longer are the best things in life free. To attain a safe, enjoyable environment, we shall have to pay higher prices for certain goods and services so that funds will be available for pollution control. In direct actions, we may have to abandon such accepted practices as elaborate packaging of goods. We may have to ban the automobile from urban areas, and I wonder how many of us would be prepared to make the choice between our wheels and cleaner air.

Atmospheric pollution focuses on the automobile, not only because it is blamed for more than half the pollution in America, but because it is the symbol of progress and prosperity. Even though processes are being developed and improved for the reduction of smoke and fumes, the number of vehicles on the roads continues to increase. One wonders whether the rate of reduction of pollutants will be greater than the rate of rise in automobiles.

There Is No Alternative

The pollution problem goes hand in hand with the population explosion. The most critical results of the mounting population, its concentration in cities, and its determination to achieve a higher standard of living have been the proliferation of combustion processes and the excessive discharge of water-transported wastes. Imagine how compounded the problems will be in just 30 years, when it's estimated the present world population of 3.6 billion will have doubled. We are not even certain that we will be able to feed that many people adequately. Overpopulation is going to be our major problem in the years to come. There will certainly come a time when human multiplication must stop or we will run out of living space.

If sheer weight of numbers doesn't smother us, then pollution surely will — unless we can reverse present trends. When the underdeveloped areas of the world catch up with the advanced nations technologically and economically, their ability to pollute will be magnified many fold by their large and exploding populations.

Here again, we must make a value judgment. I think it is important that we strive to give every human being on the face of the earth access to a good standard of living. But to take our way of life to disadvantaged nations under today's conditions would simply spread pollution and make it even more difficult to reverse the trend.

From now on, environmental quality must be given equal standing with material progress. There is no alternative. We have been travelling so fast down a one-way street that it is going to be difficult to shift into a different gear. It is going to take a mighty effort on the part of every concerned human being to make the change.

AIR POLLUTION CONTROL

An Urgent Problem

by MORRIS KATZ, M.Sc., Ph.D.

Two high stacks (1,000 feet) at the Conemaugh Electric Generating Station near Huff, Pennsylvania.

Air pollution has become a community problem of major importance in all of the industrialized or developed countries of the world. Mounting concern by the public and government has led to the enactment of various types of legislation in the form of Clean Air Acts or other regulations designed to reduce the emission of contaminants from major sources. Factors that have contributed to the growing air pollution problem are the "population explosion," the growth of large urban communities, the increasing combustion of fossil fuels for generation of heat and electric power, the ever-growing numbers of motor vehicles, and the continued expansion of existing and new industrial processes and products. The graver aspects of the uncontrolled emission of waste products in the community atmosphere have been emphasized by a series of acute air pollution episodes, resulting in illnesses and deaths of people during the buildup of pollutants over five-day periods of stagnant air, temperature inversions, and fog.

Many sources of atmospheric pollution are of natural origin, but nature itself provides a number of air-cleaning processes. In the lower atmosphere, chemical reactions may convert gases or vapours into solid and liquid products by oxidation, combination, condensation, or polymerization mechanisms. Photochemical reactions, especially in the upper atmosphere, may break down more complex molecules by absorption of high-energy ultraviolet solar radiation and resultant oxidation, atomic, and free radical chain reactions. On a global scale these removal or scavenging processes are remarkably effective.

Contaminants From Man-Made Sources

Concern today is directed mainly toward air contaminants from the activities of man. Major sources of these contaminants may be classified broadly as follows:

(a) Combustion of fossil fuels for generation of steam, heat, and electric power.
(b) Combustion of fuels for transportation, including motor vehicles, aircraft, trains, and vessels.
(c) Incineration of solid waste and refuse.
(d) Industrial sources.
(e) Chemical and photochemical reaction products of contaminants after discharge to the atmosphere.

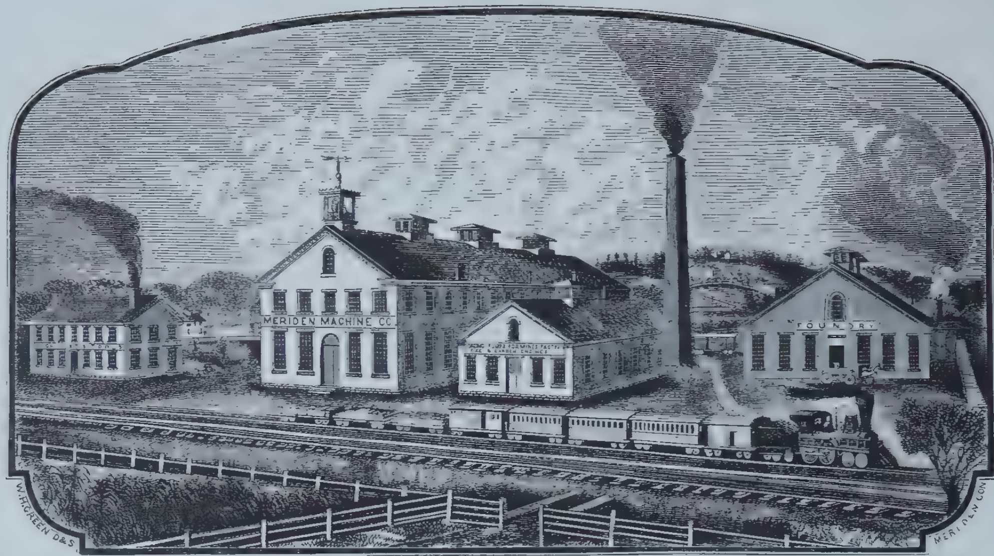
Presently, the consumption of fossil fuels in the United States alone amounts to about 1.3 billion (thousand million) tons annually. This results in the discharge of about 4 billion tons of carbon dioxide, 140 million tons of carbon monoxide, 24 million tons of sulphur dioxide, 10 million tons of oxides of nitrogen, and 5 million tons of particulate matter. In addition, relatively large quantities of hydrocarbons, aldehydes, acids, and many other organic substances are also discharged. In the aggregate, over 40 million tons of these organic vapour contaminants are discharged annually. About 99 per cent of the carbon monoxide and 44 per cent of the oxides of nitrogen can be attributed to the exhaust gas from motor vehicles.

Sulphur dioxide is a major air pollutant in many countries, especially in the United States, where the present annual emission is about 30 million tons. Of this total, about 60 per cent is derived from coal combustion and an additional 20 per cent from combustion of petroleum products. The smelting of sulphide ores accounts for about 7 per cent, and another 7 per cent, approximately, is discharged from oil refinery operations. The relatively high average and maximum concentration levels in the atmosphere of a number of large American cities have led to regulations that restrict the maximum sulphur content of fuels for electric power generation and industrial steam production to values as low as one per cent in some instances.

Existing technology and engineering control techniques are adequate to remove fly ash, dust, and fume at high efficiency from most industrial emissions of waste gas containing smoke and particulate matter. The type of equip-

"A community problem of major importance"— this is New York, but it could be almost any city in the industrialized world.

Early smelting complexes were designed to maximize production, not environmental control. Today, modern technology and advance planning can help maintain a favourable environment.



ment to be employed in a particular process depends upon the physical and chemical properties of the dust and the collection efficiency required to meet existing emission standards. Dust recovered in the steel manufacturing, base metal smelting, cement, and a number of other industries may be reused in the process.

A wide variety of gases are discharged from process industries and chemical and petrochemical plants that require engineering control techniques to prevent damage to vegetation and property, odour nuisances, and other air pollution problems. For example, steel mills may discharge carbon monoxide and fluorides; iron sintering plants and base metal smelters—sulphur dioxide; petroleum refineries—hydrogen sulphide, hydrocarbons, and sulphur dioxide; and fuel-burning electric power plants—sulphur dioxide.

Wherever these gases are present in relatively high concentrations in the waste gas streams, the removal or recovery of a specific contaminant can be accomplished usually by application of known methods. Thus, hydrogen sulphide released in petroleum refining can be converted to elemental sulphur economically. Blast furnace gas rich in carbon monoxide is usually cleaned and burned under boilers to produce steam and electric power for the steel plant. Some nonferrous metal smelters that produce a waste gas containing over two per cent sulphur dioxide can produce sulphuric acid and phosphate fertilizer economically due to proximity to available markets.

A major problem today is associated with the economical recovery of sulphur dioxide from power plant flue gas, where the concentration is of the order of 0.2 per cent or less by volume, and from weak smelter gases. The most direct step in recovery is by oxidation to sulphuric acid, after preliminary cleaning and concentrating of the gas. However, even if this could be achieved, there would still remain the problem of availability of nearby markets for disposal of the acid, since the cost of shipment over distances of more than about two hundred miles becomes prohibitive. Reduction of sulphur dioxide to elemental sulphur would be a better solution for marketing purposes, but such a process is beset with many technical difficulties. Presently, a number of sulphur dioxide recovery processes for stack gases are under investigation in the United States, several European countries, and Japan.

Dispersion Of Waste Gas From High Stacks

The concept of dispersion of gases from tall stacks to reduce maximum ground concentrations of sulphur dioxide and to control air pollution problems was developed as early as about 40 years ago in the smelting industry. The pioneer in this field was The American Smelting and Refining Company, whose research and field studies firmly established the value of the tall stack in preventing damage to agricultural crops and other species of vegetation. Its studies stressed the importance of maintaining the buoyancy of plumes by increasing stack-gas temperature and also pointed out the large differences between average and peak concentration, especially in light winds. Stacks constructed by Asarco ranged in height from about 400 to 600 feet in this earlier period. This procedure was adopted by many other smelters in the United States, Canada, and elsewhere, including International Nickel's smelters.

Tall stacks have been employed successfully to solve problems connected with aerodynamic downwash that resulted from short stacks erected on top of power plant structures. Within recent years the thermal electric power industry and many other industries have turned to the use of tall stacks as an effective and economical device for reducing air pollution at ground level. The effectiveness of the tall stack was established by field sampling observations of ground concentrations long before engineering solutions, based on theories of plume rise and diffusion, were sufficiently advanced to be employed in stack design. Within recent years almost every major industrial operation, such as a fossil-fuel power plant, oil refinery, smelter, or chemical plant, has included one or more

"It is usually simpler and more economical to plan for control of emissions in the design stage of an industrial works." An example of good planning: Inco's mining and processing complex at Thompson, Manitoba.

stacks designed to maintain ground concentrations within acceptable limits.

As an illustration of this modern trend in stack design, the average height of chimneys for coal-burning power plants in the United States in 1969 was 609 feet, as compared with a 1960 average of 243 feet. The extent of reduction in ground level concentration (GLC) and the magnitude of the area over which it occurs will depend upon the effective height of the source, the distance downwind of the source, and topographical and meteorological conditions. However, a tall stack located in open, comparatively level topography will cause a marked reduction in the maximum GLC under any meteorological conditions, at the same rate of emission, compared with the dispersion from a short stack because the maximum GLC varies inversely with the square of the effective height of the source. Under the least favourable condition of a strong temperature inversion, the plume from a tall stack will remain aloft indefinitely without producing any GLC until such time as the inversion is broken down by a change in vertical temperature gradient of the atmosphere.

The wind flow pattern over a building results in the production of standing eddies behind the building, so that pollutants from a short stack nearby or on top are brought to ground level rapidly by aerodynamic downwash. This type of problem is readily solved by stack design to remove the plume from the influence of the wake. Plants located in deep valleys or mountainous terrain pose special problems that are much more difficult to solve.

The maximum GLC is inversely proportional to the square of the effective height of the source. This term includes the physical stack height and the rise of the plume in various meteorological conditions due to the momentum and buoyancy of the waste gas. Since a stack serves only to assist in the dispersion and dilution of a pollutant under prevailing meteorological conditions but does not remove it from the atmosphere, the greatest benefit conferred on a receptor by a tall stack will lie in the region of maximum GLC. However, there is mounting evidence that tall stacks exert a favourable influence on other factors, besides dispersion, that tend to reduce concentrations even at great distances from the source.

Tall Stacks Are Effective

British experience with the performance of tall stacks for air pollution control has been highly satisfactory in the case of sulphur dioxide emissions from large power plants burning fossil fuels. This performance has been gauged accurately by means of continuous measurements of GLC with sulphur dioxide recorders to determine the background levels and those due to operation of the power plants. Since 1948, electric power plants in England and Wales have been under the control of the Central Electricity Generating Board (CEGB), and total installed capacity has been increased from about 12,000 megawatts (Mw) to 42,000 Mw in 1966. In the period 1952 to 1966 the total sulphur dioxide (SO_2) emission to the atmosphere increased about 25 per cent from about 4.5 million tons annually to 6.0 million tons. This increase was due almost entirely to generation of electric power. Fuel consumption by industry and domestic users remained substantially constant over this period. The SO_2 emission from power plants increased about threefold. However, SO_2 concentration data from 78 sampling sites across the country showed, in fact, a marked reduction in mean concentration. In this period there prevailed a strong trend toward increasing stack height and reducing the number of stacks per power station as new plants were constructed.

Although it is accepted that tall stacks effectively prevent high local concentrations of SO_2, some authorities have put forward the argument that the height of emission becomes a relatively unimportant fact at places remote from the source, so that tall stacks have little influence in the prevention of additional pollution at locations a considerable distance away. The extensive experience of the British CEGB with tall stacks does not support this view.


ASARCO

Studies of the dispersion of sulphur dioxide from a 680-foot stack at a fossil-fuel power plant at Clifty Creek in the Ohio Valley provided proof that the monitored ground level concentrations were in substantial agreement with the theoretical evaluations predicted in the design study under nearly all meteorological conditions. However, for the case of the "inversion break-up fumigation," the predicted concentrations have not been observed. This illustrates that tall stacks are effective in greatly reducing or preventing the occurrence of significant ground concentrations under inversion break-up conditions.

Tall stacks recently completed or under construction range from 800 to 1,200 feet in height. Presently, a stack of 1,250 feet, believed to be the tallest in the world, designed by the writer for The International Nickel Company of Canada to meet the SO_2 ambient air quality standard of the Ontario Air Management Branch, is under construction at Copper Cliff, Ontario. This stack design was based on the testing of plume rise and theoretical diffusion models with local meteorological observations and measurements of recorded sulphur dioxide concentrations over a five-year period at 10 continuous recording stations in the Sudbury District. The new Copper Cliff stack will replace three existing stacks, two of 500 feet and one of 350 feet, and is designed to prevent damage to the most susceptible species of vegetation in the District.

An Industrial Control Program

Industrial process operations are being subjected to increasing scrutiny by government control agencies to determine whether particulate and gaseous contaminants discharged through waste gas vents or stacks meet the limitations of emission or ambient air quality standards. Compliance with such regulations may involve difficult engineering and costly economic problems if existing plants or process units have been built without adequate planning for pollution control. It is usually much simpler and more economical to plan for control of emissions in the design stage of an industrial plant.

The best approach in planning the location of a new industrial installation in an area which is populated and industrialized is to undertake a preoperational survey to determine the existing levels of air pollutants in correlation with prevailing meteorological factors. The results of such a survey in correlation with known operational data on the emission quantities from each process unit of the proposed plant would provide the required information for design of stacks and installation of control equipment to meet ambient air quality standards or to prevent the creation of an air pollution problem. A sound appraisal of the project requires a knowledge of the specific effects of the major emissions to the atmosphere on public health and welfare, vegetation, and property in relation to topography and land use of the area. Such a preoperational survey is advantageous even in rural or semi-rural surroundings to assess background or exotic pollution levels. Some contaminants, such as sulphur dioxide, are more toxic to vegetation than to animals or humans. Fluorides are much more toxic to animals than to most species of vegetation. Hydrogen sulphide has little effect on vegetation but is obnoxious and even harmful to human life in comparatively low concentrations.

A site in a rural area under consideration may be subjected to contamination from distant sources. Suspended particulates, fluorides, sulphur dioxide, and other gases may be carried great distances from large urban centres to predominantly rural areas. The existing conditions may be tolerated without complaint by the rural population until a new industrial plant commences operations in the neighborhood.

An ideal site for discharge of stack effluents consists of comparatively level terrain in an area where the average wind speed is at least 10-15 miles per hour and where strong temperature inversions occur only rarely. The highest priority should be given to a site that is not located upwind of a populated community or of valuable agricultural land. Sufficient land should be acquired for the plant site, if possible, so that maximum ground concentrations of effluents downwind occur on company property rather than on private premises in the surrounding area. A greater degree of pollution control is required for valley sites than for level or undulating terrain, especially at low wind speeds. Stacks must be designed of sufficient height so that the effective height of the plume will allow the waste gas to be carried out of the valley rather than to be trapped below the level of the surrounding hills.

Modern control measures for smelters, steel, aluminum, oil refinery, pulp mills, and other large plants should include the most efficient, practicable equipment to remove smoke, dust, and toxic gases, and to prevent the occurrence of harmful ground concentrations or damage to farm or forest lands. The usefulness of tall stacks in reducing maximum GLCs to meet the limitations of ambient air quality standards should not be overlooked in this connection. Industrial management through the benefit of good public relations may be of assistance to local planning and zoning authorities to insure that heavy industries will not be located too close to residential areas in relation to prevailing winds and other meteorological conditions. In the zoning of land for industrial use, due consideration must be given to all factors which govern the diffusion and dispersion of atmospheric contaminants, including topography of the area, frequency and speed of prevailing winds, and relative stability of the atmosphere.

A Continuing Process

It is sound practice for the management of a large plant or a group of industries to support continuing aerometric surveys of the concentrations of major contaminants in an industrial area and to make such data available to government agencies. In Canada, such studies sponsored by industry, in cooperation with

High stacks are getting higher: At Asarco's El Paso smelter, a new 826-foot stack towers over two earlier 400-foot stacks.

One of nature's air cleaning processes helps preserve the beauty of Yosemite National Park: "Carbon dioxide, released by all forms of life during respiration, is assimilated by green plants in photosynthesis."

PICTURE CREDITS

Page 24: Dan J. McCoy (Black Star)
Page 25: Pennsylvania Electric Company
Page 26: The Bettmann Archive
Page 28: American Smelting and Refining Co.
Page 30: John Cornell

government organizations, have been conducted for many years in the Sudbury District, in Montreal East, in the Sarnia area of Ontario, in a number of districts in Alberta, and elsewhere.

The International Nickel Company of Canada, Limited has maintained an active interest in air pollution control throughout the history of its nickel-smelting operations in the Sudbury District of Ontario and in the Thompson area of Manitoba. Inco was among the pioneers in the early application of high stacks, about 40 years ago, for the diffusion and dispersion of sulphur dioxide and in the removal of dust and smoke by electrostatic precipitation. An efficient metal processing and agricultural research organization has been maintained to study and assess the effects of sulphur dioxide on vegetation and methods for the removal of this gas from process units or stack effluents. Inco has also participated in the activities of the Ontario Special Sulphur Dioxide Committee, formed about 25 years ago to study the occurrence, distribution, and effects of sulphur dioxide in the Sudbury District on farm crops and forest species and to consider appropriate remedial measures.

With respect to removal and recovery of sulphur dioxide by conversion to sulphuric acid, this control phase also has a long history extending back to the 1930 decade. The program of sulphuric acid production from smelter gas has been conducted in cooperation with Canadian Industries Limited. Sulphuric acid capacity has been expanded consistently with rising opportunities to market the product in Eastern Canada. The uranium mining industry has provided an outlet for acid produced at Copper Cliff, but this market has been subject to wide fluctuations over the past 15 years as a result of variations in demand for uranium for export.

Economic considerations may severely restrict the production of sulphuric acid. In general, this product cannot be transported over long distances economically and markets must be located within two or three hundred miles from the source of supply. Furthermore, there are several other comparatively large producers of acid in Eastern Canada. The largest demand for acid is that required for the production of phosphate or other fertilizers and uranium. Use of sulphuric acid for pickling and titanium dioxide production is decreasing as this acid is being replaced by hydrochloric acid. However, in cooperation with Inco, CIL has been producing, over the past several years at Copper Cliff, the largest quantity of acid from a single source in Canada.

The key to planning and execution of a control program lies in the available technology to control wastes and manipulate the environment. Abatement technology to control smoke, fly ash, and other types of particulate matter is known and effective. Gases represent a more subtle problem, and substances such as nitrogen oxides, mercaptans, volatile organic compounds, or others requiring a very high degree of removal may require very costly measures, or the necessary technology may be non-existent. The situation with respect to stack-gas control by removal of sulphur dioxide provides an example where present-day technology does not really exist in any practical sense. In the utility power and other industries where the stack gas contains low concentrations of SO_2 in a large volume of effluent, present technology has not produced a practical control system, although more than one dozen proposed control methods are in various stages of research and development, some in pilot-scale stages.

One of the world's leading experts on air pollution, Dr. Morris Katz is currently Professor of Chemistry at York University in Toronto. From 1965 to 1969 he was Professor of Atmospheric Sanitation at Syracuse University in upstate New York. His long professional career includes work with Canada's National Research Council, Defense Research Board, and Department of National Health and Welfare. Presently a Consultant to the World Health Organization, he has a distinguished record of service as engineer-consultant to many industrial firms.

RAILWAYS IN THE SKY

by KARL BITTNER

The need for constant rediscovery of the beauty of nature, the desire to escape from the hectic pace or humdrum rut of everyday life — these have come to be an increasingly vital part of modern living. Through the years, the goal has remained the same but the means of achieving it have changed. The Sunday promenade and the buggy ride of grandfather's day have yielded more and more to sports like hiking and skiing. Today masses of sports fans travel periodically to the hills and mountain slopes. As the rapid development of transportation continues to shrink distances, it becomes increasingly easy to go wherever fancy dictates — even up to the silent summits of the majestic Alps.

What a change the years have made! How few, formerly, were physically able to reach the top of a mountain and enjoy the view! How long and strenuous was the climb on sealskin-bottomed skis, just to be able to enjoy the fleeting zip of the downhill run! A link in the chain was missing — "mechanical climbing assistance," as aerial cableways, chair lifts, and ski tows have come to be called. Today, the virtual elimination of climbing time and effort has led to an undreamed-of boom in mountain tourism and radical changes in the technology of aerial transportation.

Challenges To Ingenuity

The Alpine countries can look back upon more than 50 years of experience in the building of aerial cableways. Until the past few years, no serious problems were posed by the construction of stations and rights-of-way in mountainous terrain. It goes without saying that high-altitude construction sites have always required the best efforts of both man and machine, but the battle against nature has never been fought so furiously as in the past few years. How did this come about?

In the early days of cableway construction, when it was decided that a line to a certain peak was to be built, the first step was always the search for an appropriate route. The shape of the terrain had to be suitable for the erection of support masts and for a favourable cable path, and the ground required careful investigation to be sure it would withstand the stresses and static loads of towers, cables, cars, and passengers.

These criteria led automatically to selection of the cable route and the location of the stations. Other considerations, such as accessibility of the lower station, parking facilities, and ski trails terminating in the vicinity of the lower station and beginning near the upper station, were not taken into account in those days. The technical problems of building and operating the cableway had primary importance.

In recent years, however, these technical considerations have been increasingly subordinated to the interests of the tourist industry and of the investors, and this trend has brought new and knotty problems. For concealed in these seemingly favourable developments are the great difficulties associated with building in locations dictated by the tourist industry. Whereas formerly cableway builders were content with an ascent into regions of medium altitude, nowadays skiing in perpetual snow and ice at altitudes of over 9,000 feet is taken for granted.

Today's Difficult Requirements

Formerly, an average cableway capacity of 300 persons per hour was considered sufficient; today, three times that figure is demanded. Such high passenger capacities, as well as the problems of building and operating under difficult conditions, make heavier demands not only on the cableway personnel, but also on the equipment.

The engineer is obliged to accept solutions which his common sense opposes, and to build structures which cannot really be called economically justifiable. He can no longer plan solely on the basis of the technical means at his

"Railways in the Sky":
(Left) *The Schilthorn-Mürren Ropeway;* (above) *Davos, a major winter resort in the Grisons Region, has the longest slope in all of Europe — The Parsenn Run.*

disposal, but must act as the executing contractor for a project which has already been established. Today, a cableway system is selected to provide the highest possible capacity at the lowest possible cost. The right-of-way must begin, if possible, in the centre of town, but in any case must always start right at the end of the ski trail, next to the parking lot. The upper station must be at the starting point of all ski runs. The aerial cableway must in every respect be situated in such a way that the skier, who is always pressed for time, never has to walk any farther than absolutely necessary. The passenger is lifted into regions which, on foot, he previously never could have reached. Skiing is now a summer sport too, and the well-prepared ski trails must permit the longest and fastest descents possible.

If you consider all these requirements from the point of view of the engineer responsible for their realization, you will see at once that serious problems are bound to arise. The given terrain can result in a cable route which may be highly questionable from an operating point of view and may even make certain restrictive measures necessary if operation is to be possible at all.

The geological conditions at the station and mast sites can be such that the necessary construction methods and the resulting costs become a heavy financial burden. Moreover, in addition to such special structural problems, continual surveillance of the equipment is normally necessary to guarantee operating safety.

Another important consideration is weight reduction—keeping the weight of individual structural elements to a minimum in order to keep down transportation costs. In this context, the design engineer is often confronted with fantastic demands whose solution is possible only by a team of experts.

Critical Materials

To win out in the never-ending struggle against the elements in the high mountains, constant vigilance is necessary. This involves selection of the very best

At Laax: a cabin for 150 people.

The Lungern-Turren-Schönbuel Cable Railway.

(Left) *A single-rope, double-installation, circulating cable railway carried 2,200 persons in each direction at the 1964-65 New York World's Fair.*
(Below) *Transport of a cabin of the Schilthorn-Mürren Ropeway by helicopter.*

materials because, for the transportation of passengers, the highest degree of safety is necessary.

Among the materials which can fulfil this requirement on a long-term basis, steel certainly comes first. Wood is now used only for temporary cableway installations, and even then only for stations and support structures. Structural steel, unalloyed, is used primarily for the cable-supporting sections at the stations and for the other support structures along the right-of-way. The cables themselves—on which so much depends—are manufactured of unalloyed carbon steel of the highest purity.

Alloyed steel, containing elements like nickel for added strength and resistance to very cold conditions, is used mainly for the highly stressed parts of the cable-car mechanism. Winter temperatures down to $-40°F$ are by no means unusual at high altitudes, and all such parts must be as light and strong as possible in this rigorous environment. A particularly critical component is the axle around which the cabin swings to compensate for the ever-changing slope of the cables; this is made of a high-strength nickel steel which remains strong and does not suffer from embrittlement in conditions of severe cold.

(Above) *The Flumserberg Ropeway.*
(Right) *Crossing nearly 11 miles (1,425 meters): the Surlej-Corvatsch cable railway at St. Moritz.*

Every movement of the cableway is a source of dynamic stress. In two-cable railways, the moving cables transmit oscillations (caused by differences in the cable tension or by the carriage when passing a mast) over the suspension bolts of the cabin to the carriage and also to the support cable. Thus, strong transitory oscillations of the entire elastic system—cables and cabin—can arise and produce extremely high mechanical stresses. Similarly, surge loads—which can amount to up to three times the static loads—are transmitted to the cabin when it crosses the rollers on the masts of single-cable systems, either directly or via the towing cable. For these reasons, the structural elements must be suited to this type of permanent stress, both in their materials and in their design.

The skier using the aerial cableway has access only to the cabin, and can judge the cableway only from the standpoint of the passenger. Most of the operating machinery is concealed from his view. In large aerial cableways, this equipment is located in a closed, heated engine room and is subject only to the actual stresses of operation. In chair lifts and ski tows, on the other hand, such protective structures would be too expensive and tend to make the operation uneconomical. The machinery is therefore exposed to the same conditions as the cabins and cables. In such equipment, nickel alloy steels are generally used for transmissions, gears, shafts, and bolts to ensure operating reliability at all times.

Safety Requires Quality

Like all other forms of transportation, the aerial cableway has, in the past few years, been faced with the problem of keeping pace with increased operating requirements. Only a decade ago, it was normal to employ a mechanic to control the cableway; today, designers are turning more and more to automation in order to obtain greater performance with a minimum of personnel. Rapid fluctuations of weather and operating conditions make it impossible for an aerial cableway to function without *any* human supervision, but automation is used to replace human effort wherever feasible. This development has gone hand in hand with an increased demand for electromechanical and electronic control equipment.

Complex regulating and control systems, combined with carefully planned surveillance and up-to-date safety installations, assure safe and reliable operation. Yet, however ingenious such systems may be, they always depend on the reliability of their smallest electric components. For example, a normal run calls for the proper opening and closing of thousands of relay contacts. These contacts—which must function perfectly at all times—are made of a special nickel-base alloy which maintains constant dimensions throughout a broad range of temperatures.

Because it is bound to a fixed route, the aerial cableway must be considered an unusual form of railroad, whose special operating conditions pose unusual technical problems. The expanding tourist industry has made aerial cableways increasingly popular, but at the same time has imposed ever more difficult conditions on their design and operation. Only materials of the highest quality can ensure the safety of the many millions of passengers carried every year.

Co-editor of the Austrian journal *International Mountain and Cable Railways Review*, Dr. Karl Bittner has been Professor of Cable and Mountain Railways at Graz Technical University since 1967. He has held the post of manager of the Technical Supervisory Authorities of the Austrian Federal Ministry for Traffic and Electricity since 1951. Between 1945 and 1951, while Assistant Professor for special railway engineering at Graz, Dr. Bittner undertook special design assignments in the transportation industry, both in Austria and abroad.

PICTURE CREDITS

Pages 32, 35, 36 (right): Von Roll
Page 33: Brodrick Haldane
Pages 34 (left), 36 (left): Comet Photo
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A WORKING BOARD

Far from the panelled elegance usually associated with board rooms, the gentlemen shown above are attending a directors' meeting. On September 11, the Board of Directors of The International Nickel Company of Canada, Limited travelled to Thompson, Manitoba. For some, it was a trip of hundreds of miles; for others, thousands of miles—with members from the United Kingdom and the United States, as well as Canada.

Inco's directors had not decided to meet in Thompson to enjoy the climate—although Board Chairman and chief executive officer Henry S. Wingate observed: "It is always good to be in Thompson. The air is the best anywhere in the world. Nature can take the credit for that, but I'm happy that Inco has done its bit to help keep this magnificent area unspoiled."

The directors came to see at first-hand and in action Inco's Thompson facilities—the world's largest integrated nickel mining and refining complex. Among the facilities is the one shown above—the open-pit Pipe mine. Together with an underground mine, this will give Pipe a daily capacity of 16,000 tons of ore. The Pipe project is part of a $1.1 billion Canadian expansion program which, upon completion in 1972, will bring Inco's nickel production in Canada to 600 million pounds per year.

Photograph by Earl Kennedy

INTERNATIONAL NICKEL

MAGAZINE

1970/4

The Cover

Flowers... and exotic flowers, at that! A rather surprising cover for the quarterly journal of a mining and metal-marketing company? Not to regular readers of INTERNATIONAL NICKEL MAGAZINE who have become accustomed to reports on Inco's worldwide search for nickel and on its development into forms of increasing usefulness to modern civilization.

This rare and often unique flora provides a vivid introduction to Cofimpac's exploratory operations in New Caledonia. Other articles in this issue call attention to the varied activities of a truly multinational company. Product research in Birmingham, England, and field exploration on the Indonesian island of Sulawesi; a Royal Visit in Manitoba, and a president's address in Colorado; restoring an English cathedral, and growing grass in Ontario—all are associated with the multi-faceted work of this worldwide organization.

This quarterly magazine of the worldwide International Nickel organization is published in Canadian, French, German, Italian, United Kingdom, and United States editions.
Special editions are published for Benelux and Spain, with bound-in synopsis of the text in Dutch and Spanish.

Robert J. Quinlan, Ph.D., Editor-in-Chief

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Flowers of a New Caledonian tree from the trumpet-vine family, **Deplanchea**

NEW CALEDONIA– A BOTANICAL MUSEUM

by HENRI DE CAMARET

On the approximately 77,000 square miles of New Caledonia's mainland and surrounding islands, there exist some 3,500 species of higher plant life, almost all of which are endemic. Furthermore, they are endemic to certain very limited areas. For example, it has been reported that of the 34 species of coniferous plants in New Caledonia, 27 are peculiar to the south, only three are found in the north, and the other four are common to the whole territory.

It is true that the notion of something being endemic is an ambiguous one. Even today it is still difficult to determine to what extent certain species are purely indigenous or, on the contrary, have evolved from plants existing elsewhere—in this instance, particularly Australia or New Zealand. Unlike its neighbours, however, New Caledonia has no eucalyptus trees and its grasses have no peculiar characteristics.

A striking phenomenon is that New Caledonia emerged from the waters of the Pacific in the Tertiary, some 45 million years ago—if not before. The origin of several species of the plants that have been studied, however, dates back to the Mesozoic, nearly 100 million years earlier. The only plausible explanation is that this vegetation existed on "Tasmantia," a supposed land that once lay between the present-day Australian continent and New Caledonia.

As the earth's surface contracted, the dry land disappeared into the sea and the island we know today emerged. The vegetation growing on the land that has disappeared managed to spread to the new lands and has survived to this day. In any case, it cannot be denied that the isolation in the South Pacific of the New Caledonian mainland and the Loyalty Islands gives their vegetation a completely particular character, and makes New Caledonia one of the stars of the world of flora.

A Botanical Tour

If we approach the island by way of the mangrove swamps along the seashore, we would quickly encounter the inextricable tangle of the mangrove roots. These sombre-barked rhizophoraceous plants *(Rhizophora* and *Bruguiera),* which can grow to a height of nearly 26 feet, perch precariously on a tangled mass of aerial roots resembling wild wooden hair with tresses writhing convulsively in the mud. We would approach the mainland by the east coast much more willingly. Here we would find sandy beaches shaded by coconut palms.

Perhaps we may find a screen of columnar pines *(Araucaria cookii)* 165 feet high, lining the edge of a nearby cliff. Straight and tall, their dark cylindrical trunks piercing the sky, these trees are a typical sight of the New Caledonian coast. Here we encounter a famous treasure of New Caledonian vegetation—the coniferous trees, or gymnosperms. There are 40 endemic species in this group alone, of which 12 are araucarias. These trees are often wrongly called "pines" (just as some trees that are locally called "oaks" or "beeches" do not, in actual fact, belong to the oak or beech groups).

The study of gymnosperms corrobo-

The editors are most appreciative of the work of Gerard Aymonin, Deputy Director of the Paris National Museum of Natural History, and Dr. H. S. McKee, an Australian botanist working in New Caledonia—who acted as consultants for this article.

Dubouzetia (Elaeocarpus family)

Geissois (Lighwood family)

Metrosideros (Myrtle family)

rates what I have said earlier about the endemic characteristics of New Caledonian plant life. The genus *Podocarpus* is also found in Malaysia, Africa, and South America in the form of large trees, but in New Caledonia it is only a shrub. Behind the coconut palm tree, there begins the coastal forest of screwpines—"bouraos" *(Hibiscus tiliaceus)*, banyans, "tamanous" *(Calophyllum inophyllum)*, and "kohus" *(Afzelia bijuga)*. Sandalwood trees, which have been excessively exploited, are now rare.

Savannah And Scrub

Further inland the savannah unfolds as far as the eye can see; here the "niaoulis," or paperbark tree *(Melaleuca leucadendron)*, grows in great profusion; this is the "national" tree, which nature protects from bush fires by an extremely thick bark. Every day these twisted trees, with their sparse foliage, increase their exclusive domain, spreading into areas where fire has destroyed all other forms of plant life.

Today they cover thousands of acres, giving a very particular appearance to the island's west coast when their whitish bark creates in the sunshine colour contrasts with the dry grasses. Contrary to what is normally thought in New Caledonia, this same species of paperbark tree is also found in Australia, but there it grows behind the mangrove swamps.

Once past the savannah and the lantana country, we come upon the maquis, a scrub area which is found in lowlands on the laterites of the mining terrain. It would be worth spending a little more time here, at the side of a devoted botanist. Indeed, the floral vegetation that we are about to find would, in itself, justify a journey to New Caledonia.

Meagre shrubs, all of them endemic, live in poor circumstances on the red, ferruginous soil on heaps of peridotite rock, turning their glossy leaves toward the heavens and bursting forth, under this blue sky, with flowers of intense colours. Their particular characteristics, such as the profusion with which they occur, are extraordinary. Here are the *Montrouziera sphaeroida*, a member of the "Hoop" family (Guttiferae), with their red flowers; the *Geissois pruinosa*, a frail shrub which produces the astonishing flowers popularly known as "bottle-brushes"; and the *Dubouzetia acuminata*. Certain Cunonia produce magnificent purple or red flowers, as does its ramiflorous relative, *Geissois magnifica*. The genus *Xanthostemon* with its red or yellow blossoms, a member of the Myrtaceae family, is generally very localized. Among these shrubs grow orchids such as *Caladenia carnea* and *Eriaxis rigida*.

The Highland Forest

Whatever be the untamed floral beauty of the maquis, the wanderer may well prefer the New Caledonian forest, often difficult to reach (Mont Humbolt, Mont Panié, and the Montagne des Sources); sometimes within a few miles of Nouméa (Mont Koghi); but, in any case, quite near a road (the Col des Rousettes). Spreading along the ridge of the great mountain chain and scattered down the mountainsides, the forest reveals itself to our astonished eyes. After passing a sparser vegetation, where we see the trees of the genus *Jambosa*

A cluster of Myrtaceae flowers

Geissois sp.

A species of orchids

Xanthostemon sp. (Myrtaceae)

with their monocaul trunks crowned by a tuft of broad leaves (one of the most curious species found there), we directly enter the fascinating tropical forest. Enormous kauris, "hoops" *(Montrouziera cauliflora),* "arbres absinthes" *(Canarium oleiferum),* "chênes blancs" *(Flindersia fournieri),* "chênes rouges" (trees of the family Cunoniaceae), "bois bleus" *(Hernandia cordigera)*, "curieux" *(Symplocos arborea)*, "tamanous" *(Calophyllum montanum),* and "citronelles" *(Cryptocarya odorata)* form a canopy of green which hides us from the world outside. It is a vast natural cathedral whose columns can sometimes be more than a thousand years old. The columnar mountain pines alone occasionally rise above the nave, like huge spears. Some are 165 feet in height but with a trunk that is no more than 3½ feet in circumference.

All these mighty trees, with their thick buttress-like roots, support a tangled mass of parasitic creepers bearing such magnificent flowers as the *Amylotheca pyramidata* and *Amyena scandens,* both with red blossoms and more often found in the maquis. In the shelter of this vegetation live the immense tree ferns, whose thick stalks are decorated with a headdress of lacy leaves and which reach a record height of 80 feet. Finally, in the humid, shifting half-light, broken here and there by sudden flashes of sunshine, grow little groups of young conifers. Sometimes a tree will bear unexpected flowers in the darkness, such as *Delplanchea speciosa* with its yellow blossoms. Palm trees grow here in profusion, and the ground is covered with a thick carpet of moss and ferns.

Plants And Scientists

The first known report on the flora of New Caledonia and the Isle of Pines was evidently that compiled by the Forsters, father and son, who accompanied Captain James Cook on his second voyage. This voyage, undertaken for scientific purposes, began a great investigation—one that is still being carried on. French, British, Americans, Australians, New Zealanders, Swiss, and Dutch all became intensely interested. Today, in addition to the work carried out by individuals, L'Office de Recherche Scientifique et Technique Outre Mer (ORSTOM) employs four botanists on the spot. A herbarium has been set up, the fruit of five years' research, and there is another herbarium at the Paris Museum. An Australian botanist, Dr. H. S. McKee, is employed by the National Centre for Scientific Research to collect for the Paris Museum. All this extensive work has by no means exhausted the subject. The Museum has so far published three comprehensive accounts of plant families—the Sapotaceae, the Proteaceae, and the Pteridophytes—but these are only three among the 150 families found in New Caledonia.

Not infrequently a botanist will bring back a new species from a long and difficult expedition into the forest or the bush. As a result, a systematic inventory has not yet been completed, but the Museum of Natural History in Paris is working on this, employing several botanists, some of whom are foreigners—Americans and New Zealanders particularly.

ORSTOM is more especially con-

Montrouziera sphaeroida

Freycinctia

Cunonia macrophylla

Amylotheca (mistletoe family)

Amyena (mistletoe family)

cerned with ecological botany and pedology, while the Centre Technique Forestier Tropical concentrates on forestry and the forests. But any research and classification work would be in vain unless closely combined with ecological studies, i.e., studies of plants in their environment, the distribution and grouping of plant communities, and particularly the influence of the peridotite soil on vegetation. New Caledonia has a varied ecology, too, with the mainland and the islands each having its own characteristics.

Man And Vegetation

New Caledonia's unique plant life has survived "in spite of man," that is, in spite of those who, in their ignorance, often clear the ground without thinking of the rare plant life they are gradually destroying. One example is the *Pritchardiopsis,* a palm tree which once grew in the Prony region and disappeared forever at the beginning of this century because people consumed it as a kind of common palm cabbage. This is one of the rare irreparable disasters recorded by naturalists on the island, although it cannot be compared to the ravages caused by modern man to the vegetation of the United States or New Zealand.

A species which has more alarmingly declined is the gum-oak *(Spermolepis gummifera),* an interesting type of Myrtaceae which, before the exploitation of the forest, once spread from the open country in the south to the heights of Houailou on the east coast. It would be wrong, however, to think that New Caledonia was covered by a vast tropical forest in the 19th century. We know, for instance, that the Plain of Lakes was at least partially covered with maquis scrub as early as 1880.

After reading this brief, very cursory description, it is perhaps easier to understand why this varied museum, scientifically and artistically unique, is of such great interest to the botanist and why it should inspire all mankind whose natural heritage it is, especially the inhabitants of New Caledonia themselves.

But the motivation behind the vital protection of valuable plant life is based on more than the endemicity of the unique flora; it also arises from the need to protect the soil against erosion. The natural drainage system of New Caledonia is of special significance because of the marked contours of the surface. The degree of absorption of the soil, on the other hand, is relatively low. As a result, dramatic areas of erosion have developed, as in the Thio region.

Finally, there is the touristic motivation: The development of the forests would be a great asset to the country, an asset even more valuable than the beauty of its beaches, which can be equalled elsewhere.

Currently editor-in-chief of the local ORTF office in Nouméa, Henri de Camaret has worked for ORTF (Office de la Radiodiffusion Télévision Française) since 1956. During these 15 years, and for some years earlier, his career as a radio reporter, announcer, and editor has taken him all over the world. The place names alone—Hanoi, Tangiers, Andorra, Algiers, Brazzaville, Nantes—sound like an exotic travelogue. In New Caledonia, he has become deeply interested in—and well-informed about—local flora and fauna.

Photographs by Madame R. Catala-Stucki

MORE NICKEL FOR GROWING MARKETS

In 1969, Free World nickel production was 768 million pounds; in 1970, it will be about 1,000 million pounds. Production capacity is estimated at 1,800-1,900 million pounds for 1975; by 1980, it may reach over 2,300 million pounds. The projected increase is, in a word, spectacular.

Underlying this vast expansion of nickel production is today's increasing demand for nickel. So great has been the recent demand that one company after another, one country after another, has joined the search for new sources of nickel. International Nickel, the industry's leader, today produces about half of the total, mainly from underground sulphide deposits in Canada. But some 80 per cent of the world's known nickel reserves are laterite ores —found primarily in tropical areas of South America, Central America, Australasia, and Africa. From these sources must come—for Inco and the entire industry—the greatly increased nickel production of the future.

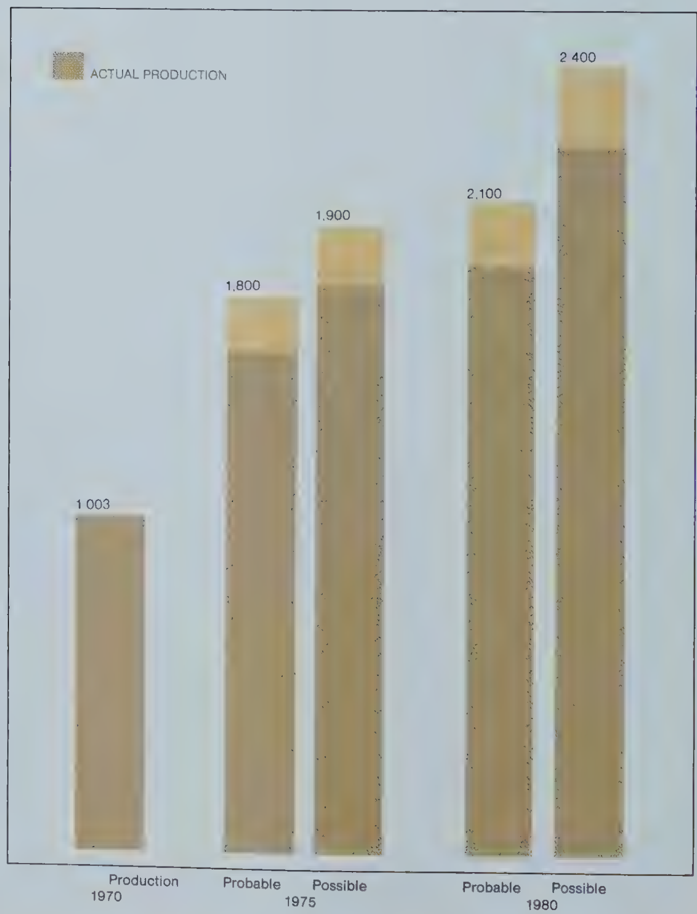
Canada, as the chart opposite indicates, will remain the Free World's largest nickel supplier, and its production will rise substantially. New Caledonia will move up dramatically, supplying four or even five times as much nickel in 1980 as in 1970. Even more fascinating is the appearance of new names—national and corporate—in the ranks of nickel producers. Australia, Indonesia, Guatemala, the Philippines, the Dominican Republic, Botswana— from little or no production these areas may move into a position of major importance.

The question in many minds, of course, is: Will nickel production increases of this size produce a glut? Most observers believe that an overbalance of supply over demand will be, if it occurs at all, only temporary. They point to the increasing demand for nickel from industries like space, marine, aviation, and pollution-control. In fact, according to Inco Chairman Henry S. Wingate, "While we may well see supply and demand come into balance in the next few months, the decade ahead is more apt to be one characterized by the struggle of producers to keep up with demand."

Some demand may, in fact, have been held back by the nickel shortage of the past few years. An increasing supply could be an important factor in creating an increasing demand.

FREE WORLD NICKEL PRODUCTION CAPACITY

(Totals shown are in millions of pounds)



A Word of Caution: The figures in both graphs are ESTIMATES. Some planned operations may take longer to go on stream than predicted; others may not go into production at all. On the other hand, expansion of some planned operations may occur and new projects may come into being.

In addition, these estimates should be further qualified. Storms and other "acts of God," strikes and other labor problems—these and other day-today possibilities associated with normal operations have to be taken into account. Actual production will probably be about 90 per cent of the capacity estimated here

FREE WORLD NICKEL PRODUCTION CAPACITY BY AREA OF ORIGIN*

*Except in the case of the imported ores and mattes on which Japanese nickel production is based. Those are dealt with under Japan, and are not included under their country of origin.

FEASIBILITY REPORT FOR COFIMPAC

Between the heavy, silver-and-white covers of A Project for Cofimpac, *there are over 100 pages of text, graphs, charts, and colour photographs. They represent thousands of man-hours of work by technical experts from many specialized fields. All together, they say: International Nickel concludes that it is technically and economically feasible for COFIMPAC to establish, in a general area which is near the southern tip of New Caledonia, a new project for the production of nickel utilizing nickel laterite ores of types never heretofore exploited on the island.*

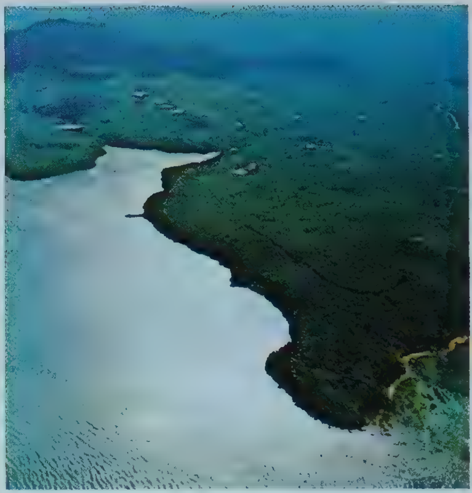
A Cofimpac operational area showing drilling grids

The island of New Caledonia possesses some of the largest known reserves of nickel in the world, all of the lateritic type. Since production began in 1874, garnierite ore—the high-nickel, low-iron laterite to which Jules Garnier attached his name—has been the only type of nickel ore mined in New Caledonia. Other types, richer in iron but poorer in nickel, had proven unamenable to economic treatment. Now, for the first time, very important types of the island's lateritic nickel ores, heretofore unusable and unused, will be mined and treated—a breakthrough that promises to bring a major boom to the nickel-

A Becker drill in operation

Mechanized equipment at work in the area

A worker



An aerial view of the townsite

producing industry. This, essentially, is the contribution that the project is preparing to make to the industry, its customers, and the world of metallurgy.

A Report Ahead Of Schedule

In April 1969, the Compagnie Française Industrielle Minière du Pacific (Cofimpac) was formed, bringing together Inco and a holding company of French industrial and banking interests, as well as the official French Bureau of Mining (BRGM). This followed a 1966 decision of the French government to approve the creation of a new nickel-producing company on New Caledonia to develop these unexploited lateritic ores. The Cofimpac agreements provide that Inco is to serve as technical consultant to the group, drawing on its wide-ranging experience and advanced technological capability. Inco's first mission was to survey the mining resources available to Cofimpac; to develop and test the techniques for processing the difficult laterite ores; to define mining, plant, and infrastructure needs; to study the manpower requirements; and to propose the means of marshalling the vast funds needed to finance the venture. From these studies was generated Inco's feasibility report for Cofimpac, presented on July 9, 1970, some months ahead of the scheduled deadline.

To reach this stage, it cost $17,000,000, of which Inco disbursed $14,000,000. The geological and exploration work involved was the most comprehensive ever conducted in New Caledonia during its century-long nickel-producing history. Some 8,000 tons of ore were removed as industrial samples and shipped to Inco's pilot plants in Canada. The laboratory and pilot-plant tests carried out there—the most extensive and most complete ever performed on lateritic ores—covered all pertinent methods of metal extraction. Most important of all, they involved tests on a semi-industrial scale.

One Hundred Million Pounds Of Nickel

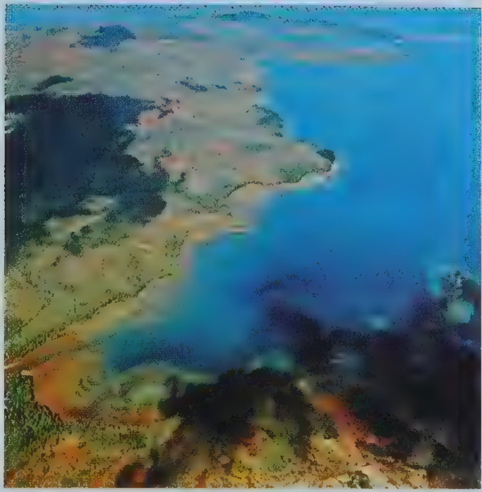
In its fully documented proposal to Cofimpac, Inco pinpoints the location for the first mining operations. This consists of mining properties situated near the southern tip of the island, which have been made available to Cofimpac by certain of its participants and through acquisitions. They have been investigated by geological and prospecting teams before 1968 by Inco alone, subsequently by Inco/BRGM teams, and finally by Cofimpac itself. Over 43 miles of drilling were completed and over 76,000 samples removed and analyzed, to permit an accurate appraisal of the deposits and the choice of proper mining techniques.

The proposed mining zones will provide enough ore for processing facilities to sustain an operation producing 100,000,000 pounds of refined nickel a year for 40 years. This means mining and transporting enough mineralized material to deliver 6,400,000 wet metric tons to the processing plant each year. Because of the consistency of the ore and its proximity to the surface, the chosen site lends itself to open-pit mining methods. This involves three major steps: removal of the overburden, that is, the surface iron capping and waste; the actual mining of the ore; and finally a clean-up operation to remove smaller pockets of ore from the irregular bottom of the ore body. The mining equipment will measure up to the Herculean size of the undertaking, and will include such mechanized giants as walking-type draglines (excavating machines with 33-foot-long booms), and haulage trucks of 91-metric-ton capacity.

What Cofimpac will extract from this mass of low-grade ore is a high purity, constant-grade metal. This in itself represents a number of major process innovations of great importance to the nickel industry. Lower-grade lateritic ores of considerably less than 2 per cent nickel content will come under direct chemical treatment. The product that emerges will be in the shape of nickel carbonyl pellets (which look like small ballbearings), the purest form of commercial primary nickel. Indeed, such a product is especially valuable for the most advanced types of metallurgical applications on which so much of modern technology depends.

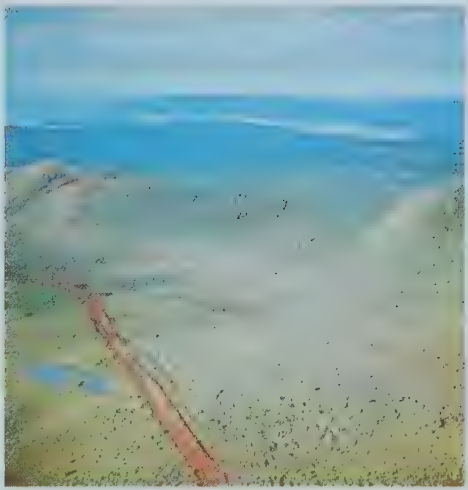
The treatment chosen to extract this high-quality metal for Cofimpac is known as the Inco Carbonyl Process for Laterites (ICPL). While no carbonyl plant yet exists for treating laterites commercially, the process has been tested in pilot-scale prototype units at Inco's facilities, on bulk samples of New Caledonian ores. The comprehensive pilot-plant program assessed the relative merits of three competitive processes. It confirmed Inco's expectations regarding the superiority of its carbonyl process for the treatment of these particular ores.

The essential elements and the prin-



An aerial view of southern New Caledonia

Basic construction: worker and shovel



Road-building

ciples of equipment design for this process have been well established by Inco. The company has a long experience in large-scale, closely related operations, and has spent years of continuing development work in carbonyl technology. Indeed, the latter is already widely applied to other types of ores throughout the company's installations.

Preserving Natural Beauty

The report for Cofimpac describes the processing plant to be established in New Caledonia, close to the mining site. Among its more spectacular features are six volatilizers of novel design, each nearly 20 feet in diameter and two hundred feet long.These huge, near-horizontal kilns are rotating cylindrical pressure vessels that permit the continuous admission of reduced ore and carbon monoxide, and the continuous but separate discharge of residual solids and carbonyl-bearing gases.

ICPL is basically a dry process that does not cause water pollution. Operations take place in a closed circuit and the gases are continuously recirculated. The levels of emission of pollutants expected from the ICPL plant in New Caledonia keep well within the standards established by the countries with the most pollution-conscious legislation.

Environmental control is, of course, concerned not only with the pollution of air and water, but also with pollution of beauty in the landscape. The feasibility report describes the efforts to be undertaken to restore worked-out mining areas to their natural appearance. To determine how this terrain can be reclaimed by vegetation, and how the wastes should be treated to sustain plant growth, Inco's agricultural department has been testing samples of the iron capping and of the overburden from the proposed mines, as well as carbonylization tailings from pilot-plant operations. The results are encouraging.

To support the Cofimpac project, a new town—initially planned for 7,500 inhabitants but allowing for expansion to a population of 25,000 in the ensuing years—will be established along the southern coast at Port Boise, while harbour facilities will be created a few miles away at Baie Nord. The town site takes full advantage of the extraordinary natural beauty of its coastal layout, and the urban plan provides for large parklands and wooded areas. The town design and building architecture incorporate all the facilities that will ensure unmarred landscape and seascape, as well as attractive living conditions. Thus the Cofimpac project put forward by Inco will make every effort to strike an optimum balance between the demands of industrial production and the need to safeguard New Caledonia's natural environment.

Financial And Human Investment

The estimated investment required for the project is (U.S.) $481 million. Of that sum $303 million represents the cost of the mining and processing facilities, and $99 million that of the infrastructure. Major elements of the infrastructure are housing facilities for the initial construction workers, the town, a power plant, a power transmission network, a water supply system, port facilities, and access roads. Financing costs, working capital, and pre-production expenditures account for the remainder of the capital expenses. Inco concludes in its report that Cofimpac's nickel production can be marketed under conditions which support its financial evaluation of the project.

The enormous financial investment will be matched by the human investment. The initial Cofimpac project will require the direct employment of 1,420 people in New Caledonia. Since the island's resources of professional, technical, and even general manpower are limited, a vast training program, at every level of competence, had to be designed for the project. Underlying this plan is Cofimpac's intention of training a maximum number of New Caledonian people.

Under the proposed program, Inco will assign personnel to New Caledonia to train local employees. Additionally, Cofimpac will set up a complete apprenticeship program in the electrical and mechanical skills, adapted to local conditions and coordinated with the training programs already established by local authorities. Selected Cofimpac staff personnel—some 50 to 70 of them—will be invited to Canada for training in International Nickel mines, plants, and offices.

All in all, the implications of the Cofimpac project for New Caledonia's future are immense in terms of economic and industrial development,technological advance, broadened professional opportunities, and a higher standard of living. Moreover, the interests of nickel consumers all over the world will be served by the successful implementation of this enterprise.

Photographs by Lance Nelson

Photographs by Don Newlands

A Royal Visit

THOMPSON, Manitoba, July 10—The dateline on the news stories and press releases could have been Winnipeg or Churchill—or on another day could have been Cardiff, or Sydney, or Montreal. Queen Elizabeth II was making a Royal visit to the city. But to the citizens of Thompson, the visit had a very special significance. As John McCreedy, vice president and general manager of International Nickel's Manitoba Division, put it: "The real watershed for Thompson moving from a small town to maturity was the visit of Queen Elizabeth." From a wilderness in 1956, Thompson had by the time of the Queen's visit grown to a modern city of more than 20,000 inhabitants, third largest in Manitoba.

Nearly all of Thompson's population turned out to welcome the Queen and the other members of the Royal Family—Prince Philip, Prince Charles, and Princess Anne. Arriving at Thompson Airport about six o'clock in the evening of July 10, the Queen and Princess Anne were greeted officially by Mayor A. Brian Campbell, Inco Vice President McCreedy, and Mystery Lake Resident Administrator Carl Nesbitt, with their wives. After a brief visit to Thompson General Hospital, the Queen and the Princess were joined by Prince Philip and Prince Charles who had paid a quick visit to the power site at Gillam.

After dinner on board the Royal Train, all four members of the Royal Family journeyed to the International Nickel display, where they were met by Vice President McCreedy and shown a pictorial display of the processes and equipment used in International Nickel operations. Accompanying the Royal Family through the display were John McCreedy with the Queen; Donald E. Munn, Inco Division Assistant General Manager, with Prince Philip; W. J. Thorpe, Superintendent of Material Control, with Prince Charles; and Ken Dillen, President of Local 6166 of the United Steelworkers of America, with Princess Anne. The scheduled 15-minute stop was stretched to 30 minutes because of the Queen's keen interest, particularly in the ore portion of the display.

From International Nickel, the Royal Family travelled to the Municipal Building, where they placed in a canister memorabilia of their visit. This was the day Thompson became a city, and copies of the City Charter were also placed in the canister. It was then sealed and will be placed in a cornerstone of the new City Hall.

The Royal Family, accompanied by the Mayor and members of his Council, took a leisurely walk through the Plaza Shopping Centre parking lot, where an estimated 17,000 persons were on hand to see the Royal visitors. About 10:30 that evening, they left the Plaza, boarded the Royal Train, and departed for an overnight trip to The Pas. It was a brief but eventful—and, for the people of Thompson, Manitoba, unforgettable—Royal visit.

SAVING YORK MINSTER

by BERNARD M. FEILDEN

Three years ago a horrifying discovery was made. York Minster, premier church of the north of England and one of the famous buildings of the world, was in danger of structural collapse. Immediately a team of architects, engineers, surveyors, and archaeologists was assembled to save this priceless architectural gem, the largest Gothic building in the country. At the same time an appeal was launched by the late Lord Scarborough to raise the £2,000,000 required to finance the vital restoration work. Bernard Melchior Feilden, Surveyor of the Fabric of York Minster and leader of the team, describes the fight against time to save this priceless building.

York Minster is a symbol of the North, the pride of Yorkshire, and part of England's national heritage. The farmer looks up from his fields and sees the three towers which dominate the Vale of York; the townsman sees the Minster from different angles as it reappears behind an ever-changing foreground of medieval shops and houses. Support for the appeal to save the Minster came from all over Yorkshire—from miners and citizens of all the great towns. All the parishes in the diocese have shown their love for their mother church, and money has also come from all the other dioceses in the Archbishopric of York.

As the architect privileged to lead the team now working on the Minster, I have been forced to think of its significance. Why is it there? Why so large? Why so magnificent? As a boy of ten I had begun to learn answers to these questions. Coming from a small ranch in the Okanagan Valley in British Columbia, I used to stay for holidays with my godmother in a gracious house in York. She, being a citizen of York, was immensely proud of the Minster, and, although a Quaker, used to take me to services and to wander round and show me the glass. She it was who told me the story of how this precious glass was saved after the Battle of Marston Moor when the victorious Roundheads came to York but were prevented from destroying the stained glass by the drawn sword of their own General Fairfax, a Yorkshireman. This stained glass is a priceless asset, representing over half our natural heritage of medieval glass. Among the masterpieces is the Great East Window painted by John Thornton of Coventry between 1404 and 1407—a series of scenes depicting the Book of Revelations in a window as large as a tennis court.

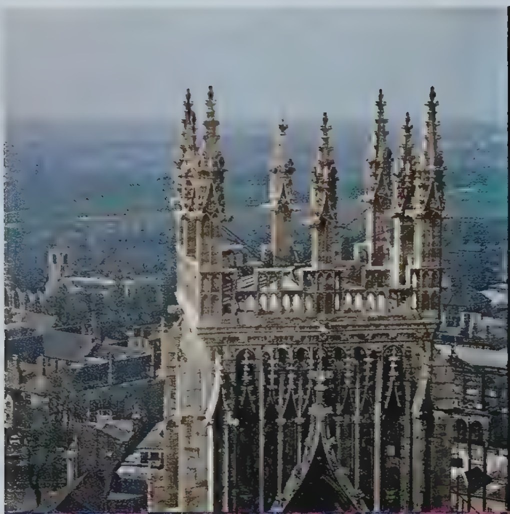
Having fallen in love with the Minster as a boy, I was very honored to be selected as Surveyor of the Fabric in 1965. This job is a little unusual. In one aspect the Surveyor of the Fabric represents the client, as he also has to undertake certain public relations tasks, such as press conferences and assistance in providing information for fund-raising purposes. In another role, he has to strike a balance between the imponderables of a full-scale exploration, get design decisions agreed upon, and keep a large and urgent contract moving at a reasonable tempo. The architectural role is more that of a conductor trying to re-interpret an historical masterpiece than that of a composer of a new score.

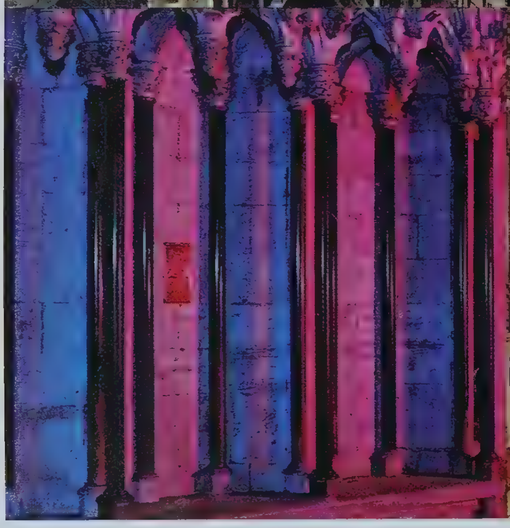
Cracks In The Piers

My first job was to get to know my charge. Having served an apprenticeship on Norwich Cathedral for some 10 years, I knew that I had to make a detailed inspection of the Minster, literally stone by stone. This took two years and resulted in a report of over 500 pages. Halfway through this work suspicions were aroused by fresh cracks in the main piers (pillars) and further fresh cracks in the Eastern Crypt. It was also obvious that the East End was well out of vertical and that the transepts were distorted.

The Dean and Chapter were informed of my concern, and authorized the appointment of Ove Arup & Partners, consulting engineers. Geoffrey Wood, one of the senior partners and himself son of a builder who used to work on Canterbury Cathedral, advised "you don't cure measles by dabbing at the spots." Translated, this meant: You may have cracks in the piers but look at the foundations. A small exploratory dig, arranged under the direction of Dr. Brian Hope-Taylor, a Cambridge University archaeologist, revealed large shear cracks, some old and some apparently new. To record any movement still taking place, glass telltales were fixed to any significant cracks. Then stainless steel gauge points were glued to the stone, and measurements to 1/100th of an inch were instituted.

As it was apparent that a major operation was probably involved, further consultations became necessary. Robert Potter, the architect of Chichester Cathedral, was asked to give his opinion on the evidence. He agreed with the diagnosis of myself and Geoffrey Wood that the foundations of the Central Tower were failing. The Central Tower, however, presented a unique problem. No temporary works strong enough to support its 16,000-ton deadweight could



(Above) *The North-West and South-West towers have been reinforced with nickel stainless steel, as have the marble columns of the 13th-century De Gray Tomb.*
(Below) *The Minster is a treasure chest of architectural styles and ecclesiastical furnishings.*

be constructed on the inadequate subsoil. It was essential to carry out the work while the structure was still strong enough to stand the surgery of building repairs. Since the East End could be supported by shoring if necessary, our immediate efforts could be aimed primarily at solving the problem of the Central Tower.

"It Can Be Done"

The Archbishop of York had appointed Lord Scarbrough as the first High Steward of York Minster. Although over 80 years old, Scarborough wanted to see for himself. He donned overalls, put on a helmet, looked into the foundations, and climbed up some 60 feet to the Triforium to see the condition of the Minster. Afterwards at tea in the Deanery he said to me: "What will it cost to repair the Minster?" I gave my estimate as between £1.7 million and £2.6 million, depending on the extent of the unknown problems we faced. After looking me in the eye for what seemed like a long minute, he said "It can be done," and he devoted the last 18 months of his life to this objective.

A team of engineers, architects, quantity surveyors, and archaeologists was brought together, and Messrs. Shepherds of York were appointed general contractors. A full-scale investigation of the subsoil was put in hand and the main piers and choir piers were strapped. In the meantime about 16 glass telltales had broken, six in one awful week. Still, work was underway and what temporary measures were possible had been put into effect. The telltales showed that the East End was also an urgent problem, and, after the digging of an exploratory hole, 80-foot steel shores were immediately ordered.

With Stainless Steel Rods

Ten alternative designs for saving the Central Tower were examined, some schemes being provided by expert contracting firms. The final scheme, however, was very like the one I had suggested to the Dean when he first saw the cracked foundations—although, needless to say, with several important improvements. It consists of a collar to prevent the upper Norman masonry bursting out, then an enlarged foundation which is clamped onto the existing masonry, using post-tensioned prestressed stainless steel rods of 1¼-inch diameter. These are fabricated from a corrosion-resistant chromium nickel stainless steel with an ultimate strength

The work of restoration: (Above) *Drilling the expanded foundations, making good the stonework, and inserting stainless steel rods into the North-West Tower.*
(Below) *Preparing the delicate tracery of the Great East Window* (left) *to receive the stainless steel ropes* (right) *that will prevent further bowing of the window, and scaffolding the interior of the massive Central Tower.*

of 60-70 tons per square inch. There are 104 rods set in two rows in each direction. These rods have to be drilled through the old masonry to unite the new and old work, forming a massive footing about 50 feet square under each pier of the Central Tower. But the new foundations do not take the load from the old until settling has taken place. To anticipate this, Ove Arup & Partners devised compression pads to go under the new foundations, and it is intended to push these into the clay subsoil about three-fourths of an inch until the new foundations share the loads with the old and reduce them from eight tons per square foot eccentric loading to three tons per square foot concentric loading. Arup's design obeys the first principle of conservation—it makes the best use of the material that exists. It is also kind to the old fabric in that it does not make the new work too strong.

Drilling through the old foundations has proved how pulverized the masonry had become due to settling of about 12 inches over the centuries. The first two rows of rods went in after nine months of slogging, but the second set has gone in rather more quickly. Looking back over the alternative designs, one can only be thankful we did not try some of them—now that we know the true condition of that hidden masonry. In work of this sort one is in the same situation as a physician who has to make decisions based on inadequate evidence.

Other work on the Central Tower has been easier. Twelve 1¼-inch stainless steel rods were inserted into each side of the tower about 120 feet above ground to counteract cracks some 1¼ inches wide that were growing at the rate of 1/16th of an inch per decade. This work exemplifies the second principle of structural conservation—the work should be invisible. After the rods had been inserted, the Minster masons made good the stonework, carving a new crocket where necessary. In addition, a new roof and wing beam have been put on top of the Central Tower.

Some Other Challenges

The North-West Tower was reinforced in a similar manner at three levels where large cracks had occurred, and about 3,500 gallons of grout were injected. At the East End, new foundations—125 feet long, 18 feet wide, and 9 feet thick—were inserted by underpinning methods, once the 80-foot steel shores had been set up. These shores each rest on four

jacks which have a constant-pressure hydraulic device to prevent damage to the Minster by thermal expansion and contraction, or from other causes.

Thornton's wonderful window gave cause for concern, for when it was scaffolded we found that the window itself bowed 9 inches more than the wall's 25-inch inclination to the east. It was impossible to take the glass out and rebuild the window, so it had to be made safe *in situ.* How? The engineers and I racked our brains. Scheme after scheme was prepared, only to be rejected as being too visible. Then we experimented with ropes on the inside of the window. As no one could say they were too intrusive, we decided upon three horizontal stainless steel wire ropes with tensioned hangers to the node points in the tracery. We believe that the natural colour of the steel will make them virtually invisible some 80 or 90 feet up in the numinous light which comes from the stained glass.

Another task confronting me was the restoration of the famous 13th-century De Gray Tomb. It had to be taken to pieces by the Minster masons and rebuilt on level foundations, but after examining the Purbeck marble columns the foreman mason advised that it would not be stable if rebuilt. The only solution was to drill each of the nine 4-inch-diameter Purbeck marble shafts, some of which were cracked, and to insert 1¼-inch stainless steel cores. The precious marble columns were wrapped in splints and plaster of paris casing, successfully drilled with diamond cores, then threaded onto the steel rods, and erected and grouted with epoxy resin.

Artistry In Stainless

Without stainless steels of the appropriate grade, the restoration techniques used in York Minster would not have been possible. For precedents in this type of work one must look to the great restoration of the piers and dome of St. Paul's Cathedral, London, in 1925-31. Here the eight piers were grouted and reinforced with stainless steel rods, as were the drum of the dome and the buttresses, and a great chain was inserted at the base of the dome to strengthen the superstructure. Now, after 40 years, it is possible to see how successful these techniques have been. If only Christopher Wren himself had had stainless steel to work with, our present problems would be simpler.

As it is widely believed that stainless steel was first developed in York, it is fitting that its use should find visible expression in the Minster, where its soft satin finish blends into the green numinous light given by the stained glass windows. Moreover, when new pews are provided in the Lady Chapel, it is proposed that they should be of oak on stainless steel frames.

How It Came To Be

Now to try to answer the questions that the Minster poses. Why is it there? For the reason, one must go back to the second phase of the Roman invasion of Britain. One Legionary Headquarters was founded at Chester to guard against the Welsh, another at York for operations against the Scots, and this continued to be the role of York down the centuries until England and Scotland were united. The archaeologists working on the Minster have shown how magnificent the Headquarters building was, with a basilica as large as the Nave of the Minster itself. Contrary to general belief, it has been proved that these buildings were used throughout the Dark Ages, and it was within the Legionary Headquarters complex that the small wooden oratory was set up in which King Edwin of Northumbria was baptized in 627 A.D. This crucial event led to the building of the first minster.

There were two successive Saxon minsters, the latter of which was burnt in 1069 at the time of the Norman invasion. The new Norman Archbishop looked to the Rhineland for a prototype and built a unique large aisleless cruciform Norman church with a clear span of 45 feet and walls some 8 feet thick. Few medieval churches in Europe are wider. Aisles were added to the Minster during its complex rebuilding which started in 1250 and ended in 1472. Thus the largest medieval building in Britain came into being, strongly encouraged by the royal influence of Edward I and Edward III and the House of York. This is how the Minster came to be so large and magnificent, and how fragments of Norman masonry came to be embedded in the main piers of the Central Tower.

During the process of enlargement a campanile was added to the Norman Tower, but this collapsed in 1406. The present massive Central Tower was built on the same Norman foundations and carried up 208 feet but not finished. The loads on the subsoil were excessive, and it is surprising that the foundations were able to support these loads so long—albeit in a state of unstable equilibrium. When this equilibrium was upset, the present restoration work became necessary and urgent. Nevertheless, this restoration is only a small incident in the eventful life of the Minster—and our engineers have designed the new foundations to last at least 500 years.

Shortly before he established his own architectural firm in 1954, Bernard Melchior Feilden, O.B.E., F.S.A., F.R.I.B.A., designed Trinity Presbyterian Church in Norwich, England. Since that time he has specialized in the restoration of historic buildings, although his firm's other projects have included banks, schools, hotels, warehouses, and offices. Surveyor of the Fabric of York Minster since 1965, he is also Surveyor of the Fabric of St. Paul's Cathedral, London. He is architect to Norwich Cathedral, consultant architect to the University of East Anglia, and the Royal Institute of British Architects representative on the British Board for Ancient Monuments.

A living masterpiece (left to right, from top): *Flying buttresses; The Eastern Crypt; The East End in winter; The reredos in the Lady Chapel; Statue representing Archbishop Thoresby; St. Stephen's Chapel; Part of the Nave; Ceiling of the Chapter House; Vaulting of the Central Tower; The Choir; Detail of the East Window; Choirboys; The Minster in early spring; The Great East Window; A pinnacle at the East End.*

Photographs by R. Maynard-Smith, International Nickel Limited

Author's photograph by P. D. Montague

MORE RYE ON THE ROCKS

International Nickel's "rye on the rocks" program of reclaiming barren tailings areas in the Sudbury District of Ontario by growing Canada blue grass, with rye as a companion crop, is a resounding success. This year, according to Inco agriculturist Tom Peters, approximately 12,000 bales of hay were harvested from the areas—and this is only half the total growth of hay. Perhaps even more important, the 700 acres supporting hay included all abandoned tailings areas.

Seven broods of ducks have been reared in the area's pond this year and frogs have been observed. Birds migrating east use it as a "drop in" centre. Trees first appeared in the area six or seven years ago. Mostly white birch, they are now standing a healthy seven feet high. Walt Whitman once remarked: "I believe a leaf of grass is no less than the journeywork of stars." Tom Peters feels the same way.

THE CHANGING TECHNOLOGY IN THE MINING INDUSTRY

by A. P. GAGNEBIN

Raise boring: "In some of the toughest rock in Canada we now bore in two weeks a 200-foot raise that formerly took two months."

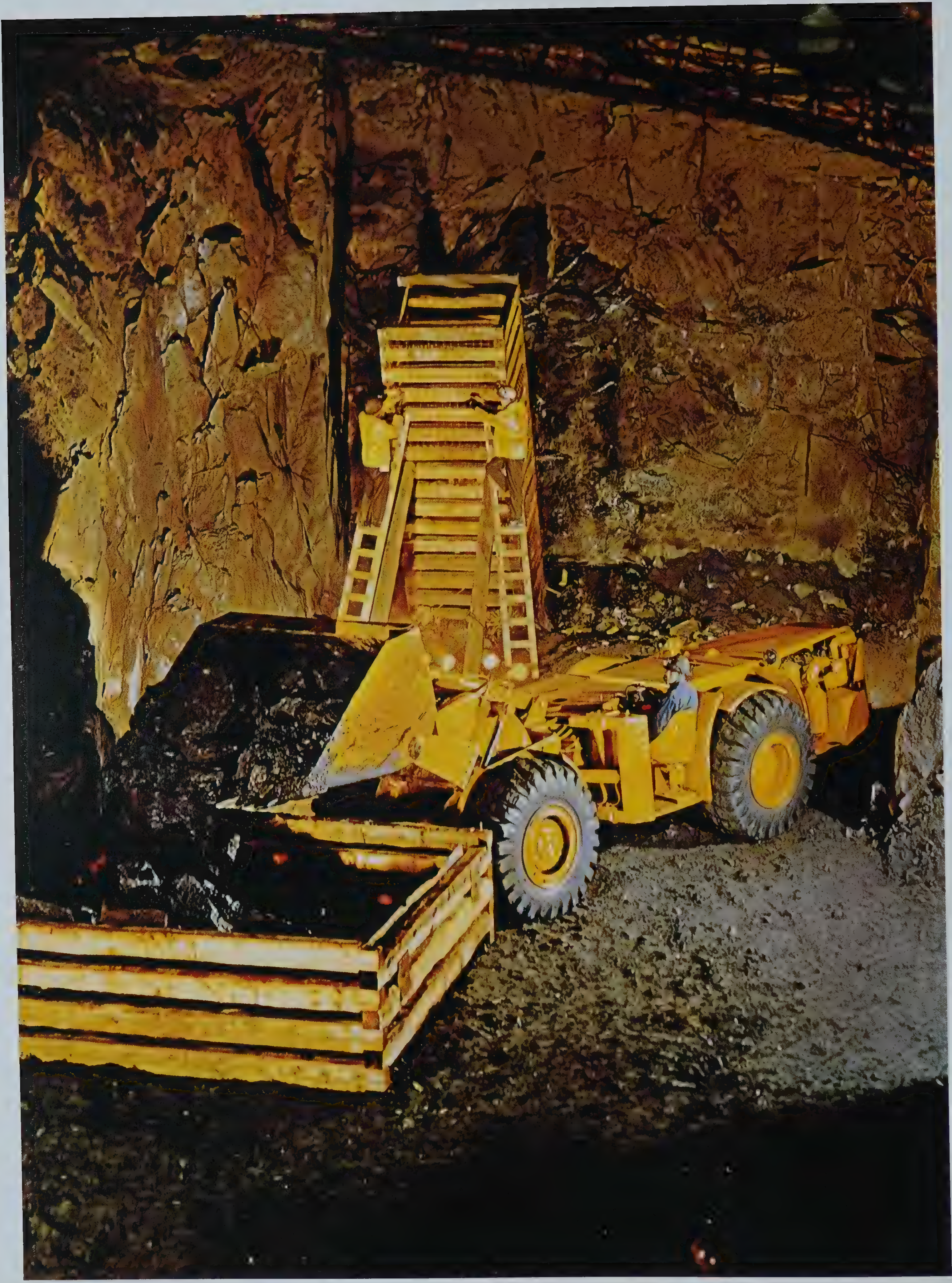
Selections from an address delivered by Albert P. Gagnebin, President of The International Nickel Company of Canada, Limited, to the opening session of The American Mining Congress Convention in Denver, Colorado, on September 28, 1970.

The challenge of change! We are living in a time when change is so rapid, and for some so overwhelming, that a new term for its impact on people has entered the language: "future shock." But change has always been a force that American enterprise has utilized to help it progress. If future shock is in fact a malady of our time, the responsibility of enterprise leadership, such as ours, is not to fall victim to it. Rather, our task is to apply the lesson that both history and experience have taught us: Change is opportunity.

To apply that lesson intelligently, we cannot afford to underestimate the size, scope, and gravity of the challenge to the mining industry. It is, in part, nothing less than a summons to scientific and technological advances well beyond anything we have achieved up to now. We shall be required continuously to accelerate our production rates even as mineral deposits become more and more difficult to find. In consequence, we shall be called upon to mine and process steadily declining grades of ore. To do so—and still make a profit—a new level of technological competence will be essential.

In exploration, the challenge is underscored by the fact that we have now covered a very large part of the North American continent in a manner that has enabled us to find the worthwhile deposits that are in the more or less obvious places. The simple fact is that virtually all the world's mines were discovered from outcroppings. Undoubtedly we have missed many of the more obscure deposits—especially mineralization that does not outcrop, which must be by far the larger part. Much of this we won't find until we have better detection methods.

Commonly used electromagnetic and induced polarization techniques are only capable of directly detecting large metalliferous deposits within some 300 feet below surface—although a recently developed EM instrument and some



specially designed IP equipment can do better than that. Another difficulty is that these devices show us anomalies, but they tell us very little about an anomaly's mineralogy that would help us to determine if it is worth drilling. In the present state of the exploration art we have to drill more than 2,000 anomalies to find one that is economic. If we could improve that batting average by even 10 per cent, we could save ourselves vast amounts of time and money.

The geophysicists appear to be confident that equipment effective at greater depth will be developed in the coming decade. They are less sanguine concerning the prospects for a detection device that will give us substantially more information about the chemical composition of anomalies than we now get—but we should work and hope for a breakthrough here.

Meanwhile, geochemical exploration, a more direct way of looking for mineral deposits, grows in stature. Over the large areas of Canada where glacial cover is heavy, the standard methods of applying chemical tests to soil, surface water, stream sediments, and vegetation have not proved of much help in detecting mineralization. But we are impressed, for example, that the sulphide nickel ore discovery in Botswana in southern Africa was the result of soil sample prospecting. Geochemical methods are proving quite effective in many parts of the world, and we may expect this trend to continue in the 70s.

An interesting new chemical technique is airborne gas detection. The "mercury sniffer," capable of detecting trace amounts of mercury in the atmosphere at low altitude, suggests the possibility that the earth may in places be giving off exhalations containing telltale traces of other elements.

Another significant advance in mineral exploration technique is the trend to deeper diamond drilling. Ten years ago in North America we thought drilling from surface to 4,000 feet was going pretty deep. Some drilling now approaches the 10,000-foot level, and we already have evidence that 15,000 to 18,000 will be feasible in the 70s.

The spectacular corroboration of the continental drift theory by a variety of recent scientific findings offers new geological insights. The implications of the theory for the exploration geologist, in all probability enormous, will be under evaluation for some time, but we are virtually certain to see major practical consequences in the coming decade. The improvements we have made and are making in exploration technology are enabling us to acquire more data than ever before—more, indeed, than up to now we have known how to use. The time is coming when we shall present masses of raw data to a computer and quickly analyze and extract the significant information.

Two factors are converging to influence mining technology. One is the continuously declining grade of ore. The other is the growing disinclination of men to take up mining for a livelihood. The first calls for lower cost methods of breaking and handling increasingly greater amounts of ore. This means greater mechanization, and mechanization makes for more skillful and attractive occupational opportunities.

In discussing mechanization I can best cite my own company's experience, since it was only four years ago that we undertook a very large investment in new mining machinery and the new operating techniques it made possible. Two developments had paved the way. One was the increasingly wider use of roof bolts for back support in drifts and crosscuts. This obviates the need for supporting timber and leaves open space in which trackless vehicles can maneuvre. The other was the advent of oxy-catalytic exhaust scrubbers that permit diesel engines to be safely operated underground. Accordingly, we converted most of our muck handling to trackless mining technique, phasing out slushers in favour of rubber-tired, diesel-powered, load-haul-dump equipment. To provide muck fast enough to keep up with these vehicles, which will soon be handling eight-ton loads, we adopted trackless, multiple-drill rigs. These mobile three-boom jumbos, together with pneumatically loaded ANFO explosive, bring down muck much faster than the slusher methods could have taken it away. To provide for transfer of load-haul-dump machines between levels we have constructed ramp systems, in some instances from surface.

This program has substantially increased the efficiency of most of our mining systems. Our new method of sublevel caving in particular depends on a full array of mechanized equipment—all operating with complete mobility in big, wide, smooth-paved crosscuts and haulage ways.

This particular combination of caving technique and ore handling suits the Sudbury conditions. Elsewhere, in other mines under other conditions, different new procedures are under development.

"We converted most of our muck handling to trackless mining technique, phasing out slushers in favour of rubber-tired, diesel-powered, load-haul-dump equipment."





The imperatives of declining grades of ore will dictate the prevailing mining trend in the 70s: new, more efficient procedures for bringing ore down in great volume, and highly mechanized equipment capable of handling it in huge unit loads or high-capacity conveyor flow.

Raise boring is another great step forward in reducing costs, as well as improving safety. In some of the toughest rock in Canada we now bore in two weeks a 200-foot raise that formerly took two months. The logical extension of raise boring is tunnel boring of drifts and other horizontal passages, and from what I have been hearing recently, this could well become common practice before the end of the decade. The improvements in material handling will come thick and fast, but will we get better, faster ways of breaking rock? We can use improvements all along the line here—faster drills, new hole-driving methods, new ways of breaking. And nuclear blasting is coming.

The extension of the bulk mining principle to extractive metallurgy is large-scale, continuous-flow processing. The basis for processing low-grade ores has long been beneficiation to unlock the valuable minerals from the rock and discard the bulk of the rock as early as possible. This century's most important single development in the mining industry has been ore concentration by froth flotation. This made it possible to process great tonnages that otherwise would never have qualified as ore. Yet few if any of us would maintain that the advantages to be derived from froth flotation have as yet been fully realized. Some believe that in the past the nonferrous industry has been overdependent on refinements in mineral dressing practice, to the point where these have served to sidetrack incentive to invent new ways to beneficiate ores and to treat the beneficiated output. Now those long submerged needs are asserting themselves.

Beneficiation in the decade ahead will include methods quite different from conventional mineral dressing practice. Leach-precipitation-float circuits in the case of copper oxide ores, and leaching of uranium ores followed by ion exchange or solvent extraction of the metal may be regarded as forms of beneficiation. Solution mining—the leaching in place of large volumes of broken ore—is being tested on copper ores. Solution mining is also being tried in the uranium and potash industries. It may well prove a significant development of the 70s.

A need exists to devise a way to beneficiate oxide ores, such as those of copper and nickel, where the metal compounds are in quasi-molecular subdivision. By this I mean, no matter how finely these ores are ground, every particle still contains metal value. Hence they cannot be concentrated by physical means, as in conventional mineral dressing. About the only procedures we presently know are two chemical methods—thermal upgrading and segregation, the latter usually referred to as the Torco process.

In metals extraction, the need to protect the environment has become critical. In my opinion, it is going to rank along with cost in its influence on process planning and plant design. New mines and new plants will have full provision for eliminating, treating, or conditioning pollutants that affect plant and animal life, air, and water.

Extractive metallurgy will advance on many fronts. The possibilities are all but limitless. To call the roll is to indicate the lengthy gamut that technological innovation can run in the 70s: electrical energy utilization—high vacuum processing—inert gas atmospheres—fluid bed techniques—packed towers—shock cooling—high temperature solid-liquid separation—vapour phase chemistry—chloride chemistry—fused salt chemistry—plasma chemistry—high temperature aqueous chemistry—bacterial leaching—solvent extraction and non-aqueous liquids—electrolyzing of metal compounds. And many more. The long held promise of the computer to make fully automated process control a reality can be realized if the problems of devising accurate, reliable, continuous sensing devices are overcome. And that advance will bring within reach the full advantages of continuous-flow extractive procedures from raw ore to finished metal.

The mining industry's changing technology: (left, above) *A rotary-percussion drill at work in Western Australia;* (right, above) *three-boom jumbos have revolutionized operating techniques in Sudbury mines;* (left, centre) *analysis by atomic absorption analyzing machine in the field in Indonesia;* (left, below) *a huge dredge removing tons of overburden at the Pipe Mine near Thompson, Manitoba;* (right) *liquid carbonyl storage tanks in use in Port Colborne pilot-plant tests of the carbonyl extraction process.*

PICTURE CREDITS
Pages 25, 28 (upper right): Derek Wing, Inco Canada
Page 26: Arthur d'Arazien
Page 28 (centre) Peter Warburg
Page 28 (lower left): Clive Webster
Page 28 (lower right): John Cornell

INDONESIAN ORE IN CANADA

On a brisk October day the motor ship *Ina Lotte Blumenthal* arrived off the Great Lakes port of Hamilton, Ontario. A short time later she eased up to a dock. She had completed a long voyage to Canada—more than halfway around the world.

To most people, this was hardly an unusual event. Freighters tie up at the Hamilton docks every day. But the *Ina Lotte Blumenthal* carried an unusual cargo: 2,666 metric tons of nickel-containing ore from the Indonesian island of Sulawesi. Some of it was packed in barrels and crates, but most of the ore was stored in bulk in the hold. The voyage had been a long one; the 3,000-ton German registry ship had set sail from Sulawesi on August 13.

This shipment of ore—destined for the Port Colborne research stations of The International Nickel Company of Canada, Limited—was the first large quantity sent to Canada for processing on a pilot-plant scale by P. T. International Nickel Indonesia. Since July 1968, when a contract was signed with the Government of the Republic of Indonesia toward the establishment of a nickel-producing project on the island of Sulawesi, exploratory work has been under way. In determining whether development of a large mining and processing facility would be economically feasible, evaluation of the ore—first in laboratory samples, then in bulk quantities for commercial processing—is a vital step. Thus the arrival of the *Ina Lotte Blumenthal* in Canada marked an important development stage in the Indonesian project.

What will happen next? Speaking to the Toronto Society of Financial Analysts on September 23, James C. Parlee, Inco's Senior Executive Vice President, reported: "In Indonesia, our work has moved from the exploration to the early development stage. Our program calls for us to be in a position near the beginning of next year to present to the Indonesian Government a plan for proceeding to a producing operation."

Where the ore came from: A Becker hammer crew at work at Soroako in Sulawesi.

Photographs by Lance Nelson

INVESTMENT IN RESEARCH

at Inco's Birmingham Laboratory

Birmingham Laboratory (left) *as it looked in 1936, and an architect's impression* (right) *of how it will look in 1972.*

In April 1969, work began on a $2.4 million redevelopment program at International Nickel's product research laboratory in Birmingham, England. When completed, the program will ensure that the laboratory, already one of the best equipped for industrial metals research in Europe, will have the facilities needed to develop the even more advanced and sophisticated materials that industry will be seeking during the next decade.

The challenge facing the metallurgist today is to keep pace with—or preferably a step ahead of—the escalating demands that technology places on his skills. Every year the task becomes scientifically more complex, the objectives more difficult to meet, the timescale shorter. There can be little hope of success unless he can increase the speed at which metallurgical knowledge is gained—and this calls for original research techniques and the most advanced equipment that can be devised. The modernization program at Birmingham Laboratory recognizes this fact; it will provide Inco's metallurgists there with the means of accelerating and advancing their research effort on behalf of European industry.

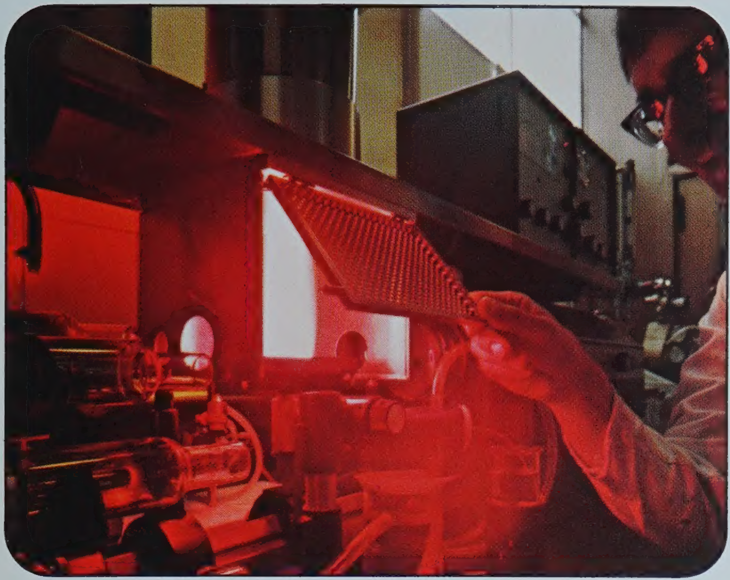
Birmingham Laboratory is one of the two principal alloy research laboratories operated by International Nickel, the other being in the United States at Sterling Forest, New York. By virtue of their locations—one in Europe and one in North America—they enable close liaison to be maintained with Inco's customers around the world and ensure that Inco's overall product research effort is applied to maximum effect, while taking full account of differences in national requirements. The two laboratories work in close association, conducting complementary programs of investigation and freely interchanging research results. This ensures that new materials or processes arising from industrial requirements in one area of the world can swiftly be made available, adapted as necessary, in other areas.

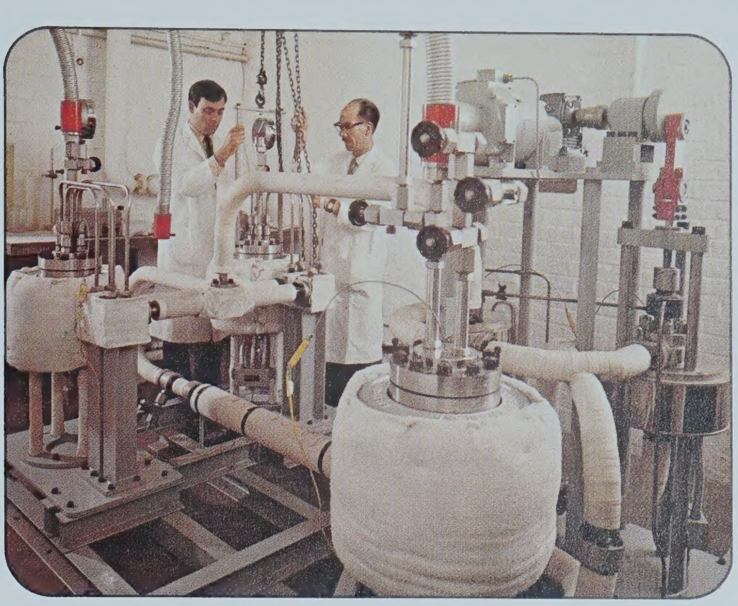
A Particularly Flexible Research Tool

Redevelopment at Birmingham is on schedule and will be completed in 1972. A new metalworking section has been already commissioned. Here has been installed the largest rolling mill yet built for research work in Europe. The usefulness of a material is much influenced by how easily it can be manipulated and shaped. This involves extensive tests in a range of metalworking equipment representative of commercial practice. Unless the metallurgist has suitable equipment in the laboratory, instrumented to give him the data he needs, his development program will be hampered and delayed by the need to arrange tests in an actual metalworking plant, using production machinery ill suited to research work and available only infrequently. There will be no such problem at Birmingham Laboratory; under the redevelopment plan, an integrated metal-processing complex is being built that will meet all foreseeable requirements.

The big new rolling mill—a 400-ton unit—is a particularly flexible research tool, being capable on the one hand of operating under conditions typical of commercial practice and, on the other, of enabling unconventional rolling tech-

A latticework of girders against a Birmingham sky—a familiar sight as the laboratory's construction program got under way.





Advanced new equipment: An atomic absorption spectrometer (left) *and a rig for testing materials in a desalination plant* (right).

niques to be explored. It can, for example, simulate a commercial rolling operation in which metal is successively rolled down in a series of mills into the forms and shapes that industry requires. This means that the behavior of a particular alloy to be processed in a particular rolling operation can be predetermined in the laboratory, without a trial run in the actual plant. Conversely, if a manufacturer were to experience difficulty when rolling one of the more obdurate materials, his problem could be investigated in the laboratory without interrupting commercial production.

A second research rolling mill of much smaller size and more specialized purpose has recently been added to the metal-processing department. This high-precision machine enables metal foils less than one-tenth the thickness of a human hair to be rolled down from sheet material—an attribute of special value in the laboratory's work on platinum metals research.

In Minutes, Not Days

One of the most significant innovations under the redevelopment program will be in the laboratory's analysis department, where more than 30,000 analytical determinations are made to high standards of precision every year. Many of the alloys being analyzed are complex in composition and contain numerous different elements—some present only in minute quantities down to one part in ten thousand. A computerized X-ray spectrometer is to be installed that will analyze even the most difficult alloys in a matter of minutes—by contrast with conventional methods that can take hours, or even days.

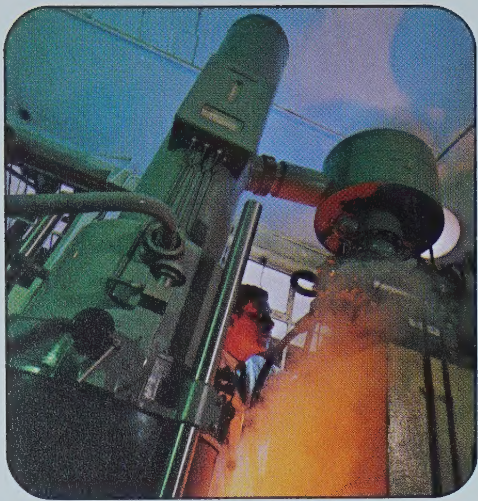
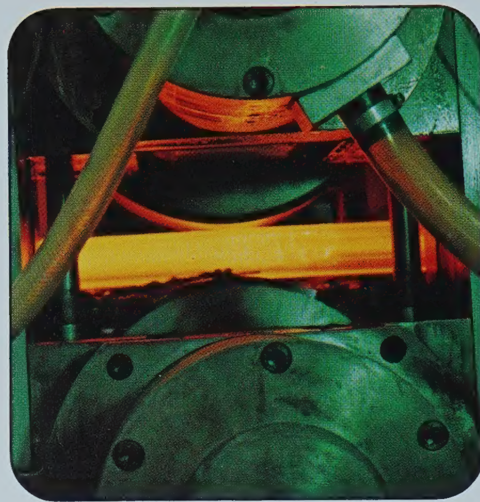
The development of this facility, which is thought to be more advanced in performance than any yet installed elsewhere in the world, is the outcome of close collaboration between the makers of the spectrometer—the Philips Company of Holland—and International Nickel. They had to face the problem of programming the computer so that it could overcome the limitations that have previously reduced the accuracy of X-ray spectrometer readings, and "read" no less than 24 different elements so that a very wide range of alloys based on nickel, iron, or copper could be accurately analyzed. This required the preparation of numerous alloy samples, all of closely controlled and known composition, and the provision of a wealth of data on nickel materials gained over several decades in Inco's alloy research programs.

Now that all this information is stored in its computer memory, the new spectrometer can perform a task not previously possible with spectroscopic equipment—it can analyze an original alloy of unknown composition. Hitherto, spectrometers worked on a comparison principle and could analyze a material only by comparing it with a standard alloy of similar composition.

An Invaluable Tool

A further addition to the laboratory's facilities is a test rig concerned with two areas of vital importance in today's world—making fresh water from the sea (i.e., desalination), and pollution. As the world population rises and the shortage of potable water becomes even more acute, large-scale desalination plants will become commonplace, often located in coastal areas near centres of population. The seawater in such places is likely to be polluted and experience has shown that this can

In the new metalworking department is the largest and most versatile rolling mill yet used for metals research in Europe.

Facilities for advanced and sophisticated research: (left) *Liquid nitrogen for cryogenic experiments is produced from air in the laboratory's own plant;* (center) *a nickel alloy billet passes through the new 400-ton rolling mill;* (right) *the computerized X-ray spectrometer for rapid analysis of alloys.*

multiply the corrosion problems of desalination equipment, leading to premature failures. The new test rig, by enabling materials to be tested in operating conditions typical of today's plants—or, when necessary, in the more onerous conditions anticipated in future equipment—will be an invaluable tool in minimizing these problems.

Making Jet Engines Possible

A major improvement in the laboratory's operations that will result from the redevelopment is the relocation of several departments in spacious new quarters. Until recent years, the laboratory was confined within a limited area of a site occupied largely by the nickel alloy manufacturing plant of an International Nickel subsidiary, Henry Wiggin & Company, Limited. The arrangement was a convenient one at the time. The laboratory, having no large-scale fabricating equipment, was able to use Wiggin's facilities to gain firsthand knowledge of the practical problems inherent in making, on a commercial scale, the more advanced nickel alloys.

This was especially helpful during the years when Inco metallurgists were developing and perfecting the famous NIMONIC* heat-resisting nickel-chromium alloys, which helped to transform Frank Whittle's early experimental jet engines into reliable power plants and made the modern jet engine possible. These remarkable materials, capable of remaining strong even when under considerable stress at red-hot temperatures, were progressively developed by the Birmingham Laboratory over two decades. They have been used in every production British jet engine ever built—including the latest, such as Rolls-Royce's *RB.211* and the *Olympus* engines of the Concorde SST.

After World War II, jet propulsion generated a large and fast-growing market for nickel alloys. This, together with an upsurge in demand by the chemical and other industries, led to the transfer of Wiggin's production from the congestion of the Birmingham works, where there was no room for expansion, to a large new plant on a "green field" site at Hereford, on the border of Wales. Thus it was that the laboratory gained the space it badly needed to expand its activities and house new equipment, including the comprehensive metalworking facility. But the buildings vacated by Wiggin were old, and renewal of the whole site was urgently needed. This is what the current redevelopment plan is fast achieving.

An Association With Nickel

The site itself is not without interest. Back in the 14th century, it formed part of the hunting grounds of the local lords of the manor. Later it became arable land and, early in the 19th century, industry made its first incursion into the area when a lead works was built. Some time afterward, probably around 1840, a nickel and cobalt refinery was established alongside the lead works by an Austrian engineer who had surreptitiously copied a refining process already in use elsewhere in Birmingham, in the works of a company called Evans and Askin. The Austrian proved to be an inadequate copyist and failed to make the process work, which was fortunate for Evans and Askin, who were able to take over the refinery and begin production there between 1842 and 1848. They did so upon the advice of a very young employee of theirs named Henry Wiggin, who later took control of the business when the partners died.

Alongside the Wiggin refinery in those early days were a galvanizing works, a foundry, and a bedstead factory. Gradually the nickel alloy business grew as "nickel silver" (an inexpensive substitute for silver consisting of nickel, copper, and zinc) became a popular basis metal for plated cutlery, and other nickel alloys began to be discovered. Eventually, Wiggin purchased the other works and occupied the whole present-day site—the site that the modernized Birmingham Laboratory will occupy when it is completed in 1972. Thus, the association of this piece of land with nickel and its alloys, begun 130 years ago, is assured.

*Registered trademark, Inco, Inc.

PICTURE CREDITS

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